PROCEEDINGS

*of the*

# Indiana Academy of Science

*Founded December 29, 1885*

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VOLUME 49

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PAUL WEATHERWAX, EDITOR

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Spring Meeting
New Harmony
May 12 and 13, 1939

Fifty-fifth Annual Meeting
Indiana State Teachers College
November 9, 10, and 11, 1939

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Copies of the Proceedings may be purchased through the State Library, Indianapolis, Indiana. All items sent in exchange for the Proceedings and all communications to officers of the Academy, when their names and addresses are not known, should also be sent to the State Library.

Reprints of certain parts of recent volumes of the Proceedings are available for distribution as follows: copies of the constitution and by-laws (Vol. 44), complete membership list (Vol. 46), and supplementary membership lists (Vols. 47-49) may be secured by members elected subsequent to the publication of those volumes; copies of the codified list of duties of officers (Vol. 48) may be secured by officers, divisional chairmen, and chairmen of committees; and copies of the necrology can be supplied to relatives and friends of the deceased members. Inquiries concerning these reprints should be addressed to the Secretary of the Academy, Dr. Wm. P. Allyn, Indiana State Teachers College, Terre Haute, Indiana.

Reprints of technical papers in recent volumes can often be secured from the authors. They cannot be supplied by the State Library nor by the officers of the Academy.

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MEMBERSHIP LISTS—The complete list of members of the Academy was last published in Vol. 46 (1937) of the Proceedings, and supplementary lists appear in following volumes. For the effect that it may have in stimulating activity, a complete list of Junior Academies is published each year as a part of the report on the Junior Academy.

CONSTITUTION AND BY-LAWS—The constitution and by-laws of the Academy were last published in Vol. 44 (1935). A codified list of duties of officers and chairmen of committees was published in Vol. 48 (1939).

EDITORIAL CODE—A general editorial code was published in Vol. 44 (1935). Additional directions for the preparation of manuscripts have been printed in leaflet form, and copies of this may be secured from the Editor.

Membership lists and copies of the constitution and by-laws may be secured from the Secretary.

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[1]Abstract.

# OFFICERS AND ELECTED COMMITTEES FOR 1939

## OFFICERS

*President*, T. G. YUNCKER, DePauw University.
*Vice-President*, L. A. TEST, Purdue University.
*Secretary*, WILLIAM P. ALLYN, Indiana State Teachers College.
*Treasurer*, W. P. MORGAN, Indiana Central College.
*Editor*, PAUL WEATHERWAX, Indiana University.
*Press Secretary*, WILL E. EDINGTON, DePauw University.
*Trustees Academy Foundation:* JOHN S. WRIGHT, Eli Lilly and Company (term expires 1940); F. B. WADE, Shortridge High School (term expires 1939).
*Committee for Bonding Trustees:* H. L. BRUNER, Butler University; W. A. COGSHALL, Indiana University.
*Research Grant Committee:* A. L. FOLEY, Chairman, Indiana University (term expires 1941); E. G. MAHIN, University of Notre Dame (term expires 1942); H. E. ENDERS, Purdue University (term expires 1940); RAY C. FRIESNER, Butler University (term expires 1939); JOHN S. WRIGHT, Indianapolis (term expires 1943); T. G. YUNCKER, DePauw University (ex officio); WILLIAM P. ALLYN, Indiana State Teachers College (ex officio).

## DIVISIONAL CHAIRMEN

*Archeology*, PAUL WEER, 1808 N. Delaware Street, Indianapolis.
*Bacteriology*, W. A. JAMIESON, Eli Lilly and Company.
*Botany*, WINONA WELCH, DePauw University.
*Chemistry*, HERMAN T. BRISCOE, Indiana University.
*Geology and Geography*, THOMAS M. BUSHNELL, Purdue University.
*Mathematics*, P. D. EDWARDS, Ball State Teachers College.
*Physics*, R. B. ABBOTT, Purdue University.
*Psychology*, AMMON SWOPE, Purdue University.
*Zoology*, C. P. HICKMAN, DePauw University.

## EXECUTIVE COMMITTEE

(Past Presidents, Officers, Divisional Chairmen, and Chairmen of Standing Committees)

Abbott, R. B.; Allyn, W. P.; Andrews, F. M.; Arthur, J. C.; Behrens, C. A.; Blanchard, W. M.; Blatchley, W. S.; Briscoe, H. T.; Bruner, H. L.; Burrage, S.; Bushnell, T. M.; Christy, O. B.; Cogshall, W. A.; Coulter, Stanley; Cumings, E. R.; Davis, J. J.; Deam, C. C.; Edington, W. E.; Edwards, P. D.; Enders, H. E.; Foley, A. L.; Friesner, R. C.; Gingery, W. G.; Hessler, R.; Hickman, C. P.; Jamieson, W. A.; Swope, Ammon; Lilly, Eli; Lyon, M. W., Jr.; Mackell, J. F.; Mahin, E. G.; Martin, E. S.; Moenkhaus, W. J.; Montgomery, B. E.; Morgan, W. P.; Mottier, D. M.; Naylor, J. P.; Noyes, H. A.; Payne, F.; Ramsey, R. R.; Rettger, L. J.; Test, L. A.; Wade, F. B.; Wallace, F. N.; Weatherwax, Paul; Weer, Paul; Welch, Winona; Wright, J. S.; Yuncker, T. G.

## STANDING COMMITTEES

(Appointed by the President, chairman of each committee named first).

**Archeological Survey:** Eli Lilly, Glenn A. Black, R. E. Esarey, E. Y. Guernsey, C. F. Voegelin, C. A. Malott.

**Auditing:** E. S. Martin, William Johnson.

**Biological Survey:** B. E. Montgomery, Winona Welch, C. M. Palmer, S. R. Esten, M. W. Lyon, Jr., B. H. Smith.

**Library:** Walter G. Gingery, Ray C. Friesner, Nellie M. Coats.

**Membership:** O. B. Christy, A. R. Bechtel, Floyd E. Beghtel, C. A. Deppe, F. R. Elliott, A. R. Eikenberry, R. E. Girton, D. L. Harmon, G. D. Klopp, F. A. Loew, M. S. Markle, R. E. Martin, H. G. Nester, Theodore Just, H. M. Powell, W. D. Thornbury, W. LeRoy Perkins, W. J. Tinkle, S. W. Witmer, J. L. Riebsomer.

**Program:** J. F. Mackell, D. L. Harmon, B. H. Howlett, B. H. Smith, Bessie Noyes, R. W. Karpinski, and Divisional Chairmen.

**Publication of Proceedings:** Paul Weatherwax, J. J. Davis, C. A. Behrens, F. B. Wade, M. E. Hufford, E. S. Conklin.

**Relation of Academy to State:** F. N. Wallace, J. S. Wright, Stanley Coulter, E. Y. Guernsey, Harry J. Reed, D. A. Rothrock.

**Representative on A.A.A.S. Council:** Howard E. Enders.

**Nominations:** Ray Friesner, C. A. Behrens, M. W. Lyon, Jr.

**Junior Academy of Science:** H. E. Enders, F. B. Wade, O. B. Christy, P. D. Wilkinson, F. J. Breeze, C. F. Cox, M. M. Williams.

# MINUTES OF THE COUNCIL MEETING

GREENCASTLE, INDIANA, MARCH 18, 1939

The meeting of the Executive Council, held in the Administration Building at DePauw University, was called to order by President Yuncker at 2:30, with the following Academy members present: R. B. Abbott, W. P. Allyn, H. T. Briscoe, T. M. Bushnell, O. B. Christy, P. D. Edwards, R. C. Friesner, C. P. Hickman, J. F. Mackell, E. S. Martin, W. P. Morgan, L. A. Test, F. N. Wallace, Paul Weatherwax, Winona Welch, T. G. Yuncker, W. A. Jamieson, Paul Weer, and A. Swope.

Officers and committees reported as follows:

**Auditing Committee.** Mr. Martin stated that the books of the Treasurer had been audited and found correct in every respect, but the books of the trustees of the Academy Foundation had not been audited.

**Treasurer.** Mr. Morgan gave a tentative report. It was stated that, inasmuch as the fiscal year for the Academy ends December 31, no complete report was available. He also stated that a complete report for 1938, approved by the Auditing Committee, would appear in Volume 48 of the Proceedings.

**Editor.** Dr. Weatherwax stated that type was all set for the 1939 Proceedings, about six weeks ahead of the previous year, and the Proceedings would be out by May. Arrangements for payment should be made by June 20. It was also emphasized that, in order to facilitate the work of the Editor, manuscripts must be in within ten days after the fall meeting.

**Research Committee.** Dr. Foley was absent but indicated by mail that no applications for the Academy Research Fund had been made. It was suggested that some means be provided to familiarize the members of the Academy with amount and purpose of funds available and with the time and methods for making application for the same.

**Program Committee.** New Harmony, Indiana, May 12 and 13, were recommended as the place and time for the spring meeting of the Academy. This recommendation met with the unanimous approval of the Council.

**Biological Survey.** Miss Welch reported that additional collections were being made and that Deam's *Flora* was now in press.

**Membership.** Dr. O. B. Christy stated that the committee had set about to interest good material in membership in the Academy. The question of how much encouragement should be given high school students to become affiliated with the Academy was discussed.

**Relation of Academy to State.** F. N. Wallace stated that a cut of 10% had reduced the state appropriation to $1,350 per year for the next two years. The Publication and Library Committees were instructed to apportion this fund for publication of the Proceedings and binding exchanges as in their judgment seemed best.

**New Business.** Dr. Weatherwax asked if the Academy wished to sponsor a meeting of the Botanical Society of America. It was decided

that a committee of four be appointed to invite the Society to meet in Indiana in 1939. President Yuncker appointed Paul Weatherwax, Ray C. Friesner, Ralph Kriebel, and F. A. Loew.

A Nomination Committee consisting of Ray C. Friesner, chairman, C. A. Behrens, and Marcus W. Lyon, Jr., was appointed by President Yuncker.

The Council adjourned at 4:45.

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## MINUTES OF THE SPRING MEETING

NEW HARMONY, INDIANA, MAY 12 AND 13, 1939

The Indiana Academy of Science convened for its annual spring meeting in New Harmony. At the regular meeting in the Murphy Auditorium on the evening of May 12, the Academy was very cordially welcomed to New Harmony and asked to partake generously of the hospitality of the city by Miss Mary E. Fauntleroy, one of the surviving pioneers who exemplifies that which New Harmony means to the history of Indiana.

During the program that followed, Miss Eva Long, native of New Harmony, read an interesting paper on "Harmonie and New Harmony." Ross Lockridge, of Bloomington, discussed the "Scientific Background of New Harmony," and S. G. Elder, of the Sun Oil Company, discussed "Recent Contributions to the Geology of Southwestern Indiana and Adjacent Parts of Illinois and Kentucky."

A short business session followed.

Dr. Foley reported that the Research Committee had granted $150 to H. T. Briscoe, of Indiana University, for research studies on measurements of di-electric coefficients and di-poles of organic compounds.

The membership committee submitted applications from ten prospective members, all of whom were elected.

Dr. Friesner of the Library Committee stated that, contrary to a previous report of a cut of 10% in the appropriation for the Academy, the State Legislature had again granted $1,500 per year for the next two years.

Dr. Weatherwax stated that the Proceedings would be off the press by the end of May. It was decided to distribute the Proceedings as soon as completed in order to avoid confusion resulting from changes in addresses during the summer.

It was also stated that an invitation, extended to the Botanical Society of America to meet in Indiana this year, had been declined because of other arrangements. It was decided to extend invitation for future date.

President Yuncker read a letter of resignation tendered by Dr. Knight, Purdue, Chairman of the Division of Psychology for 1939. The Academy ruled that the president be given power to fill such vacancies incurred between annual fall meetings. Dr. Ammon Swope of Purdue was appointed to fill this vacancy.

Dr. Test expressed the deepest appreciation of the Academy for the fine hospitality extended by the citizens of New Harmony, and a vote of thanks was extended the Tri Kappa Sorority for its assistance.

A series of tours was conducted Saturday morning. One tour was conducted under the supervision of the citizens to the interesting sites about New Harmony, reminders of the Rappite and Owen communities; another was made to observe oil developments in the vicinity; and a third was taken to Hovey's Lake, recently taken over by the State Department of Conservation.

# PROGRAM OF THE WINTER MEETING

INDIANA STATE TEACHERS COLLEGE
NOVEMBER 9-11, 1939

## THURSDAY, NOVEMBER 9

7:00-9:00 p. m. Registration.
7:30 p. m. Meeting of the Executive Committee.

## FRIDAY, NOVEMBER 10

8:00 a. m.-12:00. Registration.
9:00 a. m. General Session.
Address of Welcome—President R. N. Tirey, Indiana State Teachers College.
Response—Vice-President L. A. Test.
Selections—College A Capella Choir, Indiana State Teachers College.
Business Session.
Necrology—Will E. Edington, DePauw University.
For Memorials, see pp.
"The Days of a Naturalist"—W. S. Blatchley, Indianapolis.
"The Use of Kodachrome Slides in Teaching Limnology"—M. R. Garner, Earlham College.
1:00 p. m. Sectional meetings. See: Archeology, p. 16; bacteriology, p. 41; botany, p. 62; chemistry, p. 94; geology and geography, p. 118; mathematics, p. 175; physics, p. 179; psychology, p. 196; zoology, p. 199.
6:00 p. m. Annual Dinner.
Business Session.
8:00 p. m. "America the Beautiful"—Forum Fraternity, Indiana State Teachers College.
Selections—Rose Polytechnic Institute Glee Club.
President's Address—"Parasitism as a Way of Life," T. G. Yuncker, DePauw University (read by Dr. Winona Welch).

## SATURDAY, NOVEMBER 11

9:00 a.m. Taxonomists' Meeting. Chairman, Fred A. Loew, Huntington College. See p. xxiii.
9:00 a. m. Entomologists' Meeting. Chairman, P. T. Ulman. See. p. xxiii.
9:00 a. m. Junior Academy of Science, Business Meeting and Exhibits.
1:00 p. m. Program of Junior Academy. See p. xviii.

# MINUTES OF THE EXECUTIVE COMMITTEE MEETING

NOVEMBER 9, 1939

The Executive Committee of the Indiana Academy of Science met in the Student Lounge of the Indiana State Teachers College, November 9. The meeting was called to order at 8:00 p. m. by Vice-President L. A. Test. The minutes of the Council meeting at Greencastle, March 18, and of the spring meeting at New Harmony, March 12 and 13, were read and approved. Officers and committees reported as follows:

**Academy Trustee.** Mr. John S. Wright gave a detailed report of the Foundation funds of the Academy for 1938-1939 as follows:

**Receipts**

| | |
|---|---|
| Balance from previous year | $1,112.58 |
| Total receipts | 446.96 |
| Total | $1,559.54 |

**Expenditures**

| | |
|---|---|
| Withdrawal to purchase $1,000—3¼% Federal Farm Mortgage Corp. bond of '44-'64 | $1,093.34 |
| Balance in Indiana National Bank Savings Acct. | $ 466.20 |

**Assets in the Fund as of Nov. 1, 1939**

| | |
|---|---|
| United States Treasury Bonds | $4,700.00 |
| Consolidated Federal Farm Loan & Mort. Bonds | 2,500.00 |
| Muncie Masonic Temple Assn. Preferred Stock | 200.00 |
| Standard Oil Company of Indiana | 150.00 |
| Savings Bank Balance | 466.20 |
| Total Assets at par | $8,016.20 |

The report was accepted. It was added that the Foundation earnings were now approaching $250.00 annually and that some of these earnings might well be used for research grants to stimulate and aid research among members of the Academy.

**Auditing Committee.** A written report, submitted by the Auditing Committee, stated that the books of the Treasurer had been audited and found correct in every respect and in excellent condition. The books of the trustees of the Academy Foundation had not yet been audited.

**Biological Survey.** No formal report was rendered. Dr. Lyon of that committee expressed regret that no more activity was shown by the Biological Survey Committee. Dr. Welch of the same committee stated that her work with mosses and liverworts was being continued and that a third paper was ready for publication. It was voted that the Biological Survey Committee be asked to assemble reports of all studies completed.

**Bonding Committee.** The recommendation that the bond of each trustee of the Academy Foundation be increased to $5,000, because of the increased value of the assets of the Foundation, was approved. It

was also suggested that the chairman of the committee investigate the possibility of securing these bonds at a lower rate than that now in effect.

**Editor.** The Editor submitted the following report:

Volume 48 of the Proceedings was delivered to the State Library near the end of June. This earlier date of completion was secured through a ruling of the State Board that all work paid for out of the budget of any one fiscal year be completed before the end of that year. The following statistics indicate the cost of publication:

| | |
|---|---|
| Number of copies printed | 1600 |
| Number of pages printed | 283 |
| Cost of engraving, printing and binding | $1,434.22 |
| Cost of reprints furnished gratis | 53.15 |
| Cost of editorial assistance | 209.00 |
| Editor's expenses for postage, envelopes, mimeographing, etc. | 30.90 |
| Total cost of publication | $1,727.27 |

The net cost per printed page is considerably higher than in previous years. The difference, which is wholly in the cost of composition, is attributed to the greater condensation of material on the pages and to the unusually large amount of tabular material and other difficult composition.

The policy adopted two years ago, of making the Proceedings a complete account of the activities of the Academy for the year, has been continued, and Volume 48 contains practically all the papers presented, or abstracts of those not published in full, as well as accounts of other activities sponsored by the sections.

The provision for paying for editorial assistance in the past two years has been very satisfactory. It has reduced the Editor's work to a minimum and made possible a better publication. Probably no other expenditure made by the Academy yields any better return.

The last complete list of members was published in Volume 46 (for 1936). It would seem appropriate to publish the list again in Volume 50 (for 1940) and to expand the data about each member to indicate his interests or his institutional connections. If this is done, the information must be compiled during the coming year.

A number of recommendations made by the Editor were discussed. The appropriation of $200 for editorial assistance was continued, and the apportionment of funds for publishing the Proceedings and binding exchanges was referred to a committee consisting of the Treasurer, the Editor, and the chairmen of the Library Committee and the Committee on Relation of the Academy to the State.

**Library Committee.** A detailed report of the work of the Committee was read. Letters sent to 52 scientific societies and institutions requesting exchanges resulted in the addition of about 40 new titles, several of which are represented by long files. Complete files of some could be secured if complete files of the Proceedings were available for exchange; but volumes for 1892, 1911, 1913, 1916, 1917, 1920-1929, and 1932 are no longer available. The need for continued attention to the binding of exchange material was pointed out. Taking advantage of the low rates offered by the prison bindery, the Committee has been able to have 439 volumes bound during the year. Some comment was made on the probable effect of the European wars on the publishing activities and exchange facilities of scientific institutions in the countries involved.

**Membership Committee.** It was reported that ten new members had been elected at the spring meeting and nineteen additional applications had been received. It was suggested that a careful survey be made of the rapid changing personnel of our universities and colleges

for valuable material that was apparently being overlooked, a survey both for the benefit of the Academy and the prospective members.

**Press Secretary.** Press Secretary Edington reported that reports on the activities of the Academy had been sent to the papers of the state as occasion demanded. Through cooperation with the director of publicity at Purdue University it had been possible to secure some idea of the publicity received through the papers over the state.

**Relations of the Academy to the State.** In the absence of the chairman, Mr. John S. Wright informed the Academy that the usual appropriation of $1,500.00 by the State for the Academy was available.

**Research Committee.** The Committee announced the following awards, contingent upon the availability of the necessary funds: J. F. Mackell, Indiana State Teachers College, $50.00; W. H. Headlee, Purdue University, $100.00; and S. S. Visher, Indiana University, $25.00.

Various questions of method and policy in connection with the awarding of research grants were discussed, and the further administration of the available funds was left in the hands of the Research Committee.

**Treasurer.** The Treasurer gave a financial report for the Academy as of January 1 to October 31, 1939.

His final report, approved by the Auditing Committee at the end of the fiscal year, 1939, was as follows:

**Receipts**

| | | |
|---|---|---|
| Balance on hand January 1, 1939 | $198.43 | |
| Dues and initiation fees | 882.00 | |
| A.A.A.S. Refund for Research | 150.00 | |
| Sale of Proceedings | 6.25 | |
| Author's Reprints Vol. No. 47 | 88.78 | |
| Author's Reprints Vol. No. 48 | 132.22 | |
| Gift from a member | 250.00 | |
| | | $1,707.69 |

**Disbursements**

| | | |
|---|---|---|
| 1—Program Committee | $180.25 | |
| 2—Editor (All items of expense) | 211.35 | |
| 3—Expenses of Secretary | 55.33 | |
| 4—Expenses of Treasurer | 46.00 | |
| 5—Mailing Proceedings | 82.83 | |
| 6—Stationery | 39.05 | |
| 7—Indianapolis Engraving Co. | 121.03 | |
| 8—Wm. B. Burford Printing Co. | 563.23 | |
| 9—Junior Academy Bulletins | 20.00 | |
| 10—Safety Deposit Box and Bond | 30.50 | |
| 11—Research Grant (Dr. Briscoe) | 150.00 | |
| 12—Postage refund to officers | 2.91 | |
| 13—Returned check | 1.00 | |
| 14—Bank service charge | 1.25 | |
| | | $1,504.73 |
| Bank Balance | | 202.96 |
| | | $1,707.69 |

The donor of the $250 listed as the last item in the receipts gave permission to include this temporarily in the general fund, with the understanding that it later be transferred to the Academy Foundation.

Item No. 1 in expenditures includes a bill for $41.96 incurred by the committee for 1938 and not submitted for payment until 1939.

**Junior Academy of Science.** A written report, submitted by the Chairman and read by the Secretary, included the following points:

The Junior Academy has maintained the standard of performance of recent years. There are at present 29 clubs in good standing, with a total membership in excess of 1,000; four new clubs are recommended this year, and others are being formed. A program of merit is arranged for this year, and members of the Academy are urged to attend and to encourage the work of the Junior Academy in all ways.

The American Association for the Advancement of Science has recognized the Junior Academy movement by arranging for honorary membership in the Association for one boy and one girl from each state, these to be selected from the membership of the Junior Academies of Science.

The Executive Committee of the Academy continued the appropriation of $20.00 per year for the support of the publication of the Science Club Service. It also voted to endorse the selection of honorary members in the A.A.A.S. to be made by the Junior Academy.

**Relation of Academy to A.A.A.S.** A written report was read by the Secretary in the absence of the Chairman, calling attention to the participation of the Indiana Academy representative in the meeting of the A.A.A.S. at Richmond last winter. Further attention was directed to the interest taken by the A.A.A.S. in the Junior Academies, with special reference to the honorary membership with its awards offered to stimulate Junior Academy activities. The report was accepted.

**Committee on Nominations.** The following named persons were recommended for election as Fellows of the Academy: P. D. Edwards, Ball State Teachers College; W. A. Jamieson, Eli Lilly and Company; Fred A. Loew, Huntington College; C. P. Hickman, DePauw University; and George Hennion, University of Notre Dame.

**New Business.** The proposed selection of papers to receive honorable mention was discussed at some length. In view of the difficulty involved in making satisfactory selections in the time permitted, it was voted that action be postponed indefinitely.

On motion of its Chairman, the Committee on Archeological Survey was discontinued since its work is being done adequately by the division of Archeology.

The proposed publication of a union list of serial publications in Indiana libraries was brought to the attention of the Committee and discussed. The merits of the plan were recognized, but the Committee voted not to lend the movement financial support at this time.

The Committee declined to nominate individuals to compete for awards as outlined by the National Manufacturers' Association.

The question of the disposal of the library of the late Dr. Amos W. Butler was brought to the attention of the Committee. The advisability of the Academy's attempting to acquire this library and incorporate it in the collection now housed in the State Library was discussed at some length, but it was decided that the undertaking would not be practicable within the time limits proposed. High tribute was paid Dr. Butler for the part which he played in science in Indiana, and the hope was expressed that the library might in some way be made a living memorial of his work.

The meeting adjourned at 10:15 p. m.

# MINUTES OF THE GENERAL SESSION

FRIDAY, NOVEMBER 10, 1939

An address welcoming the Academy to the State Teachers College was given by President R. N. Tirey, followed by a response for the Academy by Vice-President L. A. Test. The College A Capella choir, under the direction of L. M. Tilson, rendered several beautiful selections in a short recital.

In a short business session the minutes of the Executive Committee meeting were read by the Secretary and approved.

Will E. Edington presented the necrology of the Academy and spoke briefly of the members lost by death during the year. Dr. W. S. Blatchley read a paper on "The Days of a Naturalist," in which he recounted his wide variety of experiences as a geologist, botanist, and zoologist.

Following the annual dinner, the Committee on Nominations presented the names of 63 applicants for membership.

The Committee also offered the following nominations for officers of the Academy for 1940: *President*, Frank Wallace, Department of Conservation; *Vice-President*, S. S. Visher, Indiana University; *Secretary*, W. P. Allyn, Indiana State Teachers College; *Treasurer*, W. P. Morgan, Indiana Central College; *Editor*, Paul Weatherwax, Indiana University; *Press Secretary*, W. E. Edington, DePauw University.

The following were nominated for election as Fellows of the Academy: P. D. Edwards, Ball State Teachers College; W. A. Jamieson, Eli Lilly and Company; Fred Loew, Huntington College; C. P. Hickman, DePauw University; George Hennion, University of Notre Dame.

The Secretary was instructed to cast the ballot of the Academy for the unanimous election of all these nominees.

Announcement was made that the following divisional chairmen had been elected in the sectional meetings: *Archeology*, Paul Weer, Indiana Historical Society; *Bacteriology*, Dona Gaylor Graam, Terre Haute; *Botany*, Ralph Kriebel, Soil Conservation Service; *Chemistry*, Karl Means, Butler University; *Geology and Geography*, William D. Thornbury, Indiana University; *Mathematics*, Cora Hennel, Indiana University; *Physics*, J. F. Mackell, Indiana State Teachers College; *Psychology*, R. A. Acher, Indiana State Teachers College; *Zoology*, W. A. Hiestand, Purdue University.

The invitation of the Ball State Teachers College was accepted and Muncie selected as the place of the fall meeting of 1940.

The report of the Resolutions Committee, recommending an expression of gratitude and appreciation for the hospitality of the Indiana State Teachers College and the work of all who helped to make the meeting a success, was approved by the Academy.

The adjournment of the business meeting was followed by the President's address.

(Signed) W. P. ALLYN, *Secretary.*


# INDIANA JUNIOR ACADEMY OF SCIENCE

Officers for 1939:

*President:* ELOISE CROSBY, North Side High School, Fort Wayne.

*Vice-President:* DONALD FRIER, West Lafayette High School.

*Secretary:* JAMES BELTZ, Elmhurst High School, Fort Wayne.

*Members of Council:* F. J. Breeze, (1935-1940); Anna Inskeep, (1936-1941); Lola Lemon, (1937-1942); J. H. Otto, (1938-1943); A. B. Krom, (1939-1944).

## PROGRAM OF NINTH ANNUAL MEETING

November 9, 1939

10:00—General Session. Eloise Crosby, North Side High School, Fort Wayne, president (Donald Frier, vice-president, West Lafayette, presiding).

10:30—"Indiana Fauna," Dr. William P. Allyn, Indiana State Teachers College.

"Interesting Facts About Animals," Jack Reeves, Lew Wallace High School, Gary.

11:30—Election of Officers.

1:00—"What Makes a Live Club?" M. M. Williams, Sponsor of Bloomington Science Club.

Short papers by members:

"Snakes," Earl Turner, Bloomington Jr. High School.

"High Frequency Electricity," Jack Porter, Wabash High School.

"Plant Growth in a Nutrient Solution," Frances Scott, Mary Sharp, Paul Shelton, Harold Blair, Arsenal Technical School, Indianapolis.

"Basic Forms of Crystals," Robert March, Shortridge High School, Indianapolis.

Reports on progress of the Indiana Junior Academy of Science in 1939, Dean Howard E. Enders, Purdue University.

## MINUTES OF BUSINESS SESSION

The annual meeting of the Indiana Junior Academy of Science was held in the Sycamore Theatre, the Laboratory School Building of the Indiana State Teachers College, Terre Haute, on November 9. The Vice-President, Donald Frier, of the Biology Club of the West Lafayette High School, presided in the absence of the President, Miss Eloise Crosby of Fort Wayne. A paper, "Interesting Facts About Animals," illustrated by slides, was given by Jack Reeves of the Lew Wallace High School of Gary. Mr. William Hopp substituted for Dr. William P. Allyn,

who was unable to appear because of illness, and gave the principal address, "Indiana Fauna," demonstrated with two reels of motion pictures. Armistice Day was observed at 11 o'clock. At that time the members of the Academy stood facing the east for a moment of silence.

Dr. H. E. Enders of Purdue University explained the present conditions upon which one girl and one boy from the Academy would be selected by the members of the Council for Honorary Membership in the American Association for the Advancement of Science. Dr. Enders also explained the advantages of membership in this organization. Ruth Downey of the Science Club of the George Washington High School, Indianapolis, and Robert Bennett of the Science Club of the Mishawaka High School were selected for these Honorary Memberships.

ROBERT BENNETT
Science Club
Mishawaka H. S.,
Mishawaka

RUTH DOWNEY
Science Club
G. Washington H. S.,
Indianapolis

C. O. PAULEY
Senior Councilor
Valparaiso H. S.,
Valparaiso

Following this portion of the program, election of officers for the coming year was held. The officers chosen were, *President*, JACK WILKIE, Elmhurst High School, Fort Wayne; *Vice-President*, DORIS SMITHA, George Washington High School, Indianapolis; *Secretary*, ROBERT KARLER of the Mishawaka High School. Mr. A. B. Krom of Wabash High School was elected member of the Council for the period 1939-1944, to succeed C. O. Pauley, Valparaiso High School, whose term expired.

After the noon intermission, Miss Anna Inskeep of West Lafayette High School presented a recommendation of the Council regarding the future selection of A.A.A.S. Honorary members. The recommendation is as follows: (1) That sponsors send nominations of candidates, plus full credentials, to the Senior Councilor at least two weeks before the annual meeting; (2) That the nominees be present at the annual meeting; (3) That they present an exhibit or a paper or some other evidence of their work at the annnal meeting.

The above recommendation was accepted with the reservation that, due to the lack of time to hear all papers, it may not be feasible for all to show evidence of their work.

Mr. M. M. Williams, Sponsor of the General Science Club of the

Bloomington High School, gave an enlightening discussion on "What Makes a Live Club?"

Dr. Enders outlined a program for the member clubs to follow during the year 1939-1940. Ten-minute papers were then presented by members of various clubs.

Six new accessions to membership in the Junior Academy of Science were announced:

1. Otter Creek Jr. Acad. of Science, North Terre Haute, Prevo L. Whitaker, Sponsor.
2. Phi-Bi-Chem Club, Lawrenceburg, H. P. Harrison, Sponsor.
3. Science Club, Central High School, South Bend, O. C. Osborne, Sponsor.
4. Biology Club, Jefferson High School, Lafayette, Kenneth Dobelbower, Sponsor.
5. Junior Science Club, Laboratory School, Indiana State Teachers College, Terre Haute, Geraldine Shontz, Sponsor.
6. State High Discovery Club, Senior High School, Terre Haute, Walter Woodrow and Frank Briggs, Sponsors.

It was announced that the next meeting of the Indiana Junior Academy of Science Clubs would be held at Ball State Teachers College, Muncie, in 1940.

One hundred twenty Junior Academy members and sponsors were in attendance.

The meeting adjourned at 4 o'clock.

DONALD FRIER, *Acting President.*
JAMES BELTZ, *Secretary.*

## EXHIBITS

The exhibits were installed Saturday morning. Keen interest was manifested by members of the visiting clubs as well as those who demonstrated their own exhibits. The following exhibits were prepared:

1. Otter Creek Junior Academy of Science Club, Terre Haute, Prevo L. Whitaker, Sponsor: Insect collections; brain dissections; crystal (chrome-alum); how to make insect net and Riker mount; tusk of mammoth.
2. Edison Academy of Science, Thos. Edison Jr. H. S., Hammond, Mac McCowen, Sponsor: Blue-printing; insect collections; wild flower herbarium; microscopic slides; leaf herbarium.
3. Phi-Chem Club, Elmhurst H. S., Fort Wayne, Ruth Wimmer, Sponsor: The chemistry of cosmetics; model airplane.
4. Geography Council, North Side High School, Fort Wayne, Fred J. Breeze, Sponsor: Maps showing drainage changes in vicinity of Fort Wayne.
5. Science Club, West Lafayette High School, Anna Inskeep, Sponsor: Silk moths.
6. Biology Club, Lew Wallace High School, Gary, Lola Lemon, Sponsor: Insect collections; leaf collections; slides.
7. Science Club, George Washington High School, Indianapolis, J. H. Otto, Sponsor: Maple leaf collection (both cultivated and native); Japanese beetle; turtles.

8. Science Club, High School, Mishawaka, Darl F. Wood, Sponsor: Working model of lime kiln; periodic chart of the elements; bird slides; flora of house gardens, catalog; finger-, hand-, and footprints.

9. General Science Club, Bloomington High School, M. M. Williams, Sponsor: Snakes; radio; chimes; artificial gas; pressure in liquids; Archimedes' principle; three states of equilibrium; fossils.

10. Nature Study Club, Arsenal Technical Schools, Indianapolis, Charlotte L. Grant, Sponsor: Demonstration of plants growing in nutrient solution; fruit collection; picture made from fruits and seeds; leaf collections; programs of club and clippings of club activities; 4 boards of nature photos (28 photographs); 2 boards of club activities (19 photographs); 4 special enlarged flower photographs; 2 posters; 3 club calendars: bird, wild flower, weather.

11. Discovery Club, State H. S. Laboratory School, Terre Haute, Walter Woodrow and Frank Briggs, Sponsors: Oil thermometer.

12. Junior Academy of Science, Greencastle, F. N. Jones, Sponsor: Exhibit of photographs, photography section directed by H. M. Stewart.

## JUNIOR ACADEMIES

| | | | |
|---|---|---|---|
| Anderson | Science | 1936 | M. J. Brozier |
| *Bloomington | General Science (Junior H. S.) | 1931 | M. M. Williams |
| | University School Science Club | 1938 | W. B. Miner |
| Cambridge City | Tri Science | 1934 | J. L. Bozarth |
| *Crawfordsville | Audubon Society | 1931 | Emmet Stout |
| East Chicago | Edison Club Roosevelt H. S.) | 1935 | Harry Apostle |
| Fort Wayne | *Geography Council (North Side H. S.) | 1932 | F. J. Breeze |
| | Science Club (North Side H. S.) | 1936 | Vesta Thompson<br>H. H. Michaud |
| | Phi-Chem Club (North Side H. S.) | 1937 | H. A. Thomas |
| | Phy-Chem (Elmhurst H. S.) | 1937 | Ruth Wimmer |
| Gary | Biology (Lew Wallace H. S.) | 1935 | Lola Lemon |
| Gas City | Science | 1936 | Roy McKee |
| Greencastle | Science | 1936 | F. N. Jones |
| Guilford | Science | 1936 | L. B. Willis |
| Hammond | Edison Acad. of Sci. (Thos. Edison High School) | 1937 | Mac McCowen |
| Indianapolis | *Crispus Attucks High School (Biology) | 1931 | C. E. Ransom |
| | Radio | | A. C. Cox, G. W. Wade and L. C. Parker |
| | Zoology | | |
| | Chemistry | | |
| | *Technical Schools—Nature Study | 1932 | C. F. Cox<br>Charlotte L. Grant |
| | *Shortridge—Chemistry | 1931 | Lois Martin |
| | George Washington Jr. H. S.—Science | 1937 | J. H. Otto |
| Lafayette | Biology—(Jefferson H. S.) | 1939 | Kenneth Dobelbower |
| Lawrenceburg | Phi-Bi-Chem | 1939 | H. P. Harrison |
| Lowell | Science | 1935 | C. N. Seeright |
| Madison | Science | 1938 | Evans Cottman |

| | | | |
|---|---|---|---|
| Marion | Science | 1936 | Mrs. Pauline Mayhugh |
| Mishawaka | Science | 1936 | Darl F. Wood |
| Montmorenci | Jr. Acad. of Science | 1933 | I. W. Vance |
| Mooresville | Science | 1936 | Fitzhugh Lee |
| Muncie | Science (Blaine Jr. H. S.) | 1934 | F. Kyger |
| New Albany | Jr. Acad. (Jr. High School) | 1935 | Gladys Knott |
| North Madison | *Hilltop Nature Study | 1931 | V. Shoemaker |
| North Terre Haute | Otter Creek Jr. Acad. Science | 1939 | Prevo L. Whitaker |
| Paoli | Science | 1935 | O. R. Whitlock |
| South Bend | Science Club (Central High School) | 1939 | O. C. Osborn |
| Terre Haute | Jr. Science Club (Laboratory School) | 1939 | Geraldine Shontz |
| | State High Discovery Club Senior H. S., Laboratory School | 1939 | Walter Woodrow and Frank Briggs |
| Tipton | Junior Academy of Science Club. | 1933 | W. D. Hiatt |
| Valparaiso | *Science | 1931 | C. O. Pauley |
| Wabash | Science | 1936 | A. B. Krom |
| West Lafayette | Science (Biology) | 1933 | Anna Inskeep |

*Charter members.

## MEETINGS OF RELATED GROUPS

As has been the custom for several years, members of the Academy interested in entomology and systematic botany held informal meetings on Saturday forenoon, November 11.

**Entomology.**—The meeting was called to order by P. T. Ulman, chairman. No formal papers were presented, but brief reviews of the past year's work were presented by A. C. Kinsey, Indiana University; L. F. Steiner, of the United States Department of Agriculture, stationed at Vincennes; and a number of workers connected with the Department of Agriculture or with Purdue University and stationed at Lafayette.

The Indiana State Teachers College, Earlham College, and Butler University were represented by students who gave reports on classroom activities in entomology.

L. F. Steiner was elected chairman of the group for 1940.

**Systematic Botany.**—The meeting was called to order by Fred A. Loew, chairman. The program consisted chiefly of a discussion of "The Limitations of the Distribution of Vegetation in Indiana." Ralph M. Kriebel gave a report on the summer field meeting held in Southwestern Indiana in September. Taxonomic notes on some Indiana plants, prepared by R. M. Tryon, were also presented.

In the symposium on plant distribution in Indiana, the following papers were presented: Flora of the Unglaciated Area, R. M. Kriebel; Relic Colonies and Boreal Flora, Winona Welch; The Prairie Flora, Scott McCoy; Dune Area and Coastal Plain Flora, Naomi Mullendore; Post-Glacial Flora, J. L. Potzger. These were discussed informally as far as time would permit.

A growing interest in the summer field meetings was expressed, and suggestions were made as to the one to be held in 1940.

Paul Weatherwax was elected chairman for 1940.

## NEW MEMBERS 1939

Allen, Donald E., 415 Maple Street, West Lafayette.
Banning, John W., R. R. 3, Attica.
Barbee, Miss Rula E., R. R. 2, Terre Haute.
Benninghoff, William, 2 Rutland Street, Cambridge, Mass.
Breneman, Dr. W. R., Indiana University, Bloomington.
Briggs, Harry E., 1330 South Fifth Street, Terre Haute.
Brost, Sister Josepha, St. Francis High School, Lafayette.
Burns, Raymond E., 213 N. Washington, Knightstown.
Campbell, William G., 104 Woodlawn Avenue, Crawfordsville.
Carlson, Dr. J. F., Purdue University, West Lafayette.
Conner, Miss Miriam E., 1027 Maple Avenue, Terre Haute.
Cowan, Dr. J. C., 210 E. Walnut, Greencastle.
Dawson, Dr. Ray F., 1009 S. College Street, Greencastle.
Dobelbower, Kenneth H., 628 N. 18th Street, Lafayette.
Doran, Ray L., 213 University Street, West Lafayette.
Easton, William Heyden, Box 174, Bedford.
Edwards, J. Gordon, 2834 Carrollton Avenue, Indianapolis.
Eisenmenger, Sister Mary Petrona. Saint Francis High School, Lafayette.
Elving, Dr. Philip J., Purdue University, West Lafayette.
Ervin, Robert Francis, 814 E. Madison Street, South Bend.
Fender, Hollis Blair, 715 West 13th Street, Bloomington.
Forsyth, Max Allyn, 714 S. 8th Street, Terre Haute.
Greenwood, Henry R., 804 E. Main Street, Washington.
Groves, Miss Carol Louise, Indiana University, Bloomington.
Guthrie, Andrew, Purdue University, West Lafayette.
Hamp, Frank A., 3251 Baltimore Avenue, Indianapolis.
Harris, Chauncy D., 624 East 8th Street, Bloomington.
Harris, Miss Louise, R. R. 1, West Terre Haute.
Harrison, Prof. H. P., 487 Ridge Avenue, Lawrenceburg.
Heap, George E., Farmersburg.
Hinkle, Miss Ruth, 427 S. Troll Street, Sullivan.
Hunter, Dr. Loraine, Clarksville, Tennessee.
Johnson, Miss Joy Dillistin, 840 DeGraw Avenue, Newark, New Jersey.
Johnson, Paul E., R. R. 2, Summitville.
Josey, Dr. Charles C., Butler University, Indianapolis.
Killeen, John Anacletus, 116 North C Street, Livingston, Montana.
Koch, Dr. G. David, Indiana State Teachers College, Terre Haute.
Kuonen, Charles E., 821 S. Grant Avenue, Crawfordsville.
Long, Dr. Alma, Purdue University, West Lafayette.
McCaskey, Miss Lois, 3551 Washington Blvd., Indianapolis.
McCowen, Max, 1554 Second Avenue, Terre Haute.
Miller, Miss Dorothy C., R. R. 4, Box 1A, Indianapolis.
Morris, D. Markland, 705 S. 14th Street, Richmond.

Morris, Miss Inez, Indiana State Teachers College, Terre Haute.
O'Neal, Mrs. Perry, 1040 W. 42nd Street, Indianapolis.
Osterman, Henry, 511 W. 6th Street, Seymour.
Ostrander, Dr. Allen R., 218 Bloomington, Greencastle.
Peters, Sister Mary Josephine, St. Francis Convent, Lafayette.
Piety, Elbert Warrick, R. R. 2, Farmersburg.
Plew, Wayne F., 214 West Donaldson, Sullivan.
Reyniers, Prof. James A., University of Notre Dame, Notre Dame.
Reynolds, Harold W., Washington.
Rose, L. Sebastian, 2236 Shelby Street, New Albany.
Sample, Dr. James H., Indiana Central College, Indianapolis.
Sandground, Dr. J. H., Eli Lilly & Company, Indianapolis.
Seaman, Lyle S., Wabash College, Crawfordsville.
Seifert, Miss Laverne, R. R. 1, Mt. Vernon.
Shields, Miss Veva, 220 E. Indiana Avenue, Bloomfield.
Shively, Dr. L. S., 2110 W. Jackson Street, Muncie.
Smith, Charles G., 1434 Haugh Street, Indianapolis.
Smith, Mrs. Fred S., 5640 Guilford Avenue, Indianapolis.
Spangler, Walter B., 210 West Jefferson, Albion.
Sparks, George R., 1724 Garfield Avenue, Terre Haute.
Vestal, Dr. A. G., University of Illinois, Urbana, Illinois.
Welborn, Dr. E. L., Indiana State Teachers College, Terre Haute.
Whitaker, Prevo L., R. R. 5, Terre Haute.
Wise, Robert E., 218 North 6th Street, West Terre Haute.
Zahnle, Vincent, 120 Sheridan Place, Lake Bluff, Illinois.

## NEW JUNIOR CLUBS 1939

Jefferson High School Science Club, Jefferson High School, Lafayette.
Phi-Bi-Chemi, Lawrenceburg High School, Lawrenceburg.
Otter Creek Junior Academy of Science, Otter Creek High School, North Terre Haute.
Junior Science Club of Laboratory School, Indiana State Teachers College, Terre Haute.
State High Discovery Club, Laboratory School, Indiana State Teachers College, Terre Haute.

# NECROLOGY

## Dominic Joseph Cannon

Scranton, Pennsylvania — Notre Dame, Indiana
May 4, 1879 — May 4, 1939

The Reverend Dominic Joseph Cannon, C.S.C., received his early education in the parochial schools of his native city, Scranton. His collegiate studies were made at Notre Dame and his theological course at Holy Cross College, an institution affiliated with the Catholic University of America in our national capital.

He was ordained to the priesthood on December 18, 1913. Until illness forced his retirement, he was active in the classrooms and laboratories of the institution, the Congregation of the Holy Cross, and as a member he took charge of the religious community. After a very successful career as teacher of physics in the University of Portland, Oregon, he transferred to the University of Notre Dame.

Father Cannon, while recognizing the value of research and doing all in his power to foster it among his students, was pre-eminently a teacher. He was at his best in the lecture hall, and it is as an inspiring and inspired teacher that his students and his colleagues will remember him.—*F. J. Wenninger.*

## Henry Chandler Cowles

Kensington, Connecticut — Chicago, Illinois
February 27, 1869 — September 12, 1939

On September 12, 1939, there passed away in Chicago one of the most prominent members of the Academy, Henry Chandler Cowles. Born in Kensington, Connecticut, on February 27, 1869, he received his early education in the schools of his native state and then entered Oberlin College, from which he graduated in 1893. He taught in Gates College for a year and then went to the University of Chicago on a fellowship with geology as his major interest. However, with the reorganization of the Botany Department at Chicago in 1896, when John M. Coulter was called there as Head, Dr. Cowles came under the influence of Dr. Coulter and a little later Charles Reid Barnes, two of the celebrated ABC triumvirate in botany, all members of the Indiana Academy, with the result that he received his doctorate in 1898, with plant ecology as his major interest. He became a member of the Department of Botany in Chicago in 1897, beginning as an assistant and finally becoming a full professor in 1911. He was chairman of the Department from 1925 to 1934, when he was retired with the rank of Professor-Emeritus.

A natural-born teacher, affable and charming in personality, and a man who attracted students to him through his jovial disposition and deep, masterly insight into his subject, Dr. Cowles became a leader and

world authority in ecology. The Ecological Society of America was founded largely through his efforts in 1914, and he wrote numerous articles and several books and textbooks which are classic. In recognition of his leadership in plant ecology he was made president of the section of phytogeography and ecology at the meeting of the International Congress at Cambridge, England, in 1930. An exponent of the field trip method of study and research, he frequently led students on field expeditions lasting from days to several weeks.

Dr. Cowles received many honors. He was president of the Botanical Society of America in 1922, president of the Association of American Geographers in 1910, vice-president of Section G of the American Association for the Advancement of Science in 1913, president of the Ecological Society in 1918, president of the Chicago Academy of Sciences from 1923 to 1934, and a member of many other scientific organizations. He was associate-editor of the *Botanical Gazette* from 1898 to 1926 and its editor from 1926 to 1934. Starred in *American Men of Science*, he was further honored by having the July, 1935, issue of *Ecology*, official journal of the Ecological Society, dedicated to him, it being filled with articles by his students and colleagues from this and several European countries.

Dr. Cowles was one of that distinguished group of American scientists who received their inspiration and encouragement from Indiana's celebrated scientists of the Jordan-Arthur-Coulter period. Primarily field men, who went directly to nature for their study, this great group—Jordan, Arthur, Coulter, Eigenmann, Branner, Everman, Cowles, and others—has left such an impression on modern science that their activity and interest in the Indiana Academy of Science redounds to its glory. This group is rapidly passing from the scene, and, with the death of Henry Chandler Cowles, international science again suffers an irreparable loss.

## MORTON W. FORDICE

Putnam County, Indiana
May 26, 1864

Putnam County, Indiana
March 1, 1939

Morton W. Fordice, one of the founders of the Indiana Academy of Science, was born on May 26, 1864, on a farm in Putnam County, Indiana, and passed away near the place of his birth on March 1, 1939. Entering Indiana University as a young man, he early came under the influence of David Starr Jordan, under whose supervision as a special student he wrote a number of papers on ichthyology published in the *Journal of the Philadelphia Academy of Science* and elsewhere. Returning to the farm shortly after his graduation in 1886, he maintained throughout the rest of his life a love for and an interest in scientific farming and scientific experimentation. In 1893 he married Miss Ella G. Williams, who survives him, together with two sons and two daughters. Both he and Mrs. Fordice were active in Republican politics of the county and district. While Mr. Fordice had been inactive in the Academy for many years, he nevertheless was actively interested in the scientific

progress of the state and was recognized as a progressive, influential farmer of broad interests, sterling integrity, and civic worth. His passing was a distinct loss to the community in which he had spent his whole life.

### THOMAS EDWARD MASON

Boone Grove, Indiana — Chicago, Illinois
October 1, 1883 — May 26, 1939

On May 26, 1939, the Indiana educational world was shocked to hear of the death in a Chicago hospital of Dr. Thomas E. Mason, a native of Indiana and a member of the Purdue University staff for twenty-five years. Dr. Mason, born October 1, 1883, in Boone Grove, Indiana, was identified with Indiana education all his life. Graduating from Indiana University in 1905, he became a Fellow at Indiana in 1911 and received the A.M. degree in 1912 and the Ph.D. degree in 1914, being the second person to receive the Ph.D. degree in mathematics from that university. He joined the mathematics staff at Purdue in 1914. During the World War he served on the Y.M.C.A. staff in France. He also spent two years in study in England. His chief interest in mathematics was in number theory and difference equations, and he had written and published several research papers in those fields. He had offered graduate courses in mathematics at Purdue for a number of years and was a joint author of two textbooks which are still widely used.

Dr. Mason was very active in scientific circles in the state and was active in the formation of the mathematics section of the Academy. He was a member of Phi Beta Kappa, Sigma Xi, the American Mathematical Society, the Mathematical Association of America, and the American Association of University Professors and a Fellow of the American Association for the Advancement of Science. He was very active in church work, being a member of the Presbyterian church, and for many years he was superintendent of the Sunday School of that denomination in Lafayette.

He was twice married, his first wife passing away in 1936. He is survived by his second wife and two daughters.

Thomas E. Mason was one of those rare individuals of broad, scholarly interests, whose home was always open to his friends. Many a lonely instructor just coming to Purdue was welcomed by Dr. and Mrs. Mason and received encouragement and friendly advice until he was established. A lover of art and rare books, his home was a place of interest to those who enjoyed his hospitality. He was a born teacher of fine and gracious personality, with a large following of students and alumni, and with his death Purdue loses one of its outstanding, influential men.

### ARTHUR G. MITTEN

Brighton, England — Goodland, Indiana
March 13, 1866 — November 23, 1938

Arthur G. Mitten was born on March 13, 1866, in Brighton, England, and came to the United States with his parents when he was nine years

old. At the age of twenty he entered the employ of the Chicago and Eastern Illinois Railroad and remained with that company until 1920, when he returned to Goodland and engaged in the purchase and improvement of numerous Benton county farms. A brother of the late Thomas E. Mitten, of the Philadelphia Transit Company, he was at the time of his death president of the Mitten Memorial Library and of Foster Park, both gifts to the city of Goodland by his brother. He was affiliated with the Goodland Methodist Church.

Mr. Mitten was deeply interested in history and archeology and was well known as a collector of historical data. He had served as a vice-president of the Indiana Historical Society. On account of his extensive researches in the history of the old Northwest Territory and William Henry Harrison, he was honored by Vincennes University with the degree of Doctor of Letters.

He was married in 1889 to Miss Adda J. Britt, who survives him; a son and a daughter also survive him.

Arthur G. Mitten was a typical dignified, distinguished English gentleman whose home was full of interest on account of its library and scientific collections. A most gracious host and a friend to everybody in his community, he was ever alert to civic needs and did much to help his community, which endeared him to all those who knew him. In his death Indiana suffers the loss of one of its leading citizens, and the Academy loses a worthy member whose intense interest in science, pursued as a hobby, accomplished much of scientific and historical value.

## JOHN L. REEVES

Kentland, Indiana
September 7, 1913

Lafayette, Indiana
June 2, 1939

John L. Reeves was born in Kentland, Indiana, on September 7, 1913, and died of an accidentally self-inflicted gunshot wound on June 2, 1939. Most of his boyhood was spent in Lafayette, but he later moved with his parents to Brookston where he graduated from high school. Becoming interested in science, he entered Purdue University where he received his degree in biology in 1936. On account of the excellence of his work he received an assistantship in the Biology Department at Purdue, which allowed him to continue his studies so that he received his Master's degree in 1938. Early in 1939 he resigned his assistantship in order to accept a teaching position in Ferris Institute, Big Rapids, Michigan. He had just returned home on his vacation a short time before his death. He is survived by his parents.

John L. Reeves was a young man of considerable scientific promise who had just begun an interesting career with that enthusiasm and persistence which was earning for him the admiration and respect of his fellow workers. In his untimely passing the cause of science suffered the loss of a young man whose scientific future seemed assured.

## ELDYN EVERETT VANLONE

Jefferson, Wisconsin — West Lafayette, Indiana
January 11, 1895 — April 5, 1939

In the passing of Eldyn E. VanLone from a heart attack while officiating at an installation meeting of the Optimist Service Club, on April 5, 1939, Purdue University lost one of its outstanding younger scientists. Dr. VanLone was born at Jefferson, Wisconsin, on January 11, 1895, and spent his early life there. He graduated from the University of Wisconsin in 1923; he also received his Master's degree in 1924 and his Ph.D. degree in 1931 from that university. He was an assistant in genetics at Wisconsin until he came to Purdue in 1932 as assistant professor of animal husbandry. In 1926 he was married to Miss Adeline Bakker, who survives him, together with his mother, one brother, and one sister.

Dr. VanLone had done and was doing outstanding research work in animal husbandry and had published a number of noteworthy papers on mammalian genetics, sterility, and the physiology of reproduction. Possessed of a pleasing personality, a thorough knowledge of his subject, and unusual teaching ability, he had attracted to him a number of students who were interested in genetical research in the breeding of live stock. He was also interested in the social and civic life of his community and was a leader in civic club activities, being a past president of the Lafayette Optimist Club.

He held memberships in the American Association for the Advancement of Science, the American Genetics Society, the American Society of Animal Production, Sigma Xi, and Alpha Gamma Rho social fraternity. Dr. VanLone was a veteran of the World War.

It is only with genuine regret that one records the passing of a scientist of Dr. VanLone's ability and prospect, and his loss to Purdue University, the Academy, and the state will be keenly felt.

PRESIDENTIAL ADDRESS

# Parasitism as a Way of Life

TRUMAN G. YUNCKER, DePauw University

Of all the various factors which influence the phenomenon of life as it evidences itself in the multitudinous variety of living organisms, those involved in the acquiring of a proper and sufficient amount of food material are unquestionably most significant. If we eliminate from consideration certain accessory substances such as minerals, those things which serve as foods, in the commonly accepted sense, are organic in nature. They supply organisms with materials for construction and repair and at the same time release energy under the destructive action of the respiratory function. Every living organism, from the most minute unicellular individual to the complex higher forms, is dependent upon a more or less continuous supply of such organic compounds which can serve these functions.

It would naturally be expected that living organisms which occur in such amazing variety of size, form, and degree of complexity would also exhibit wide differences in the manner in which they acquire their foods. When the processes and conditions involved are carefully analyzed, however, it is discovered that there are few, if any, fundamental differences in the nutritional habits of most living organisms. The foods are commonly similar in nature; they enter into the cells under essentially similar conditions and perform comparable functions for the organisms. There may be, of course, differences in the physical or mechanical features of organisms, which depend for the most part upon the presence or absence of the pigment chlorophyll, the complexity of the organism, and the type of habitat in which it lives. Green plants are rightfully recognized as the source of organic foods for most other non-green organisms, both plants and animals. It is sometimes assumed that such green plants are capable of maintaining life independent of assistance from other organisms. This, however, is found to be only partially true when a study is made of their dependence upon various materials which are obtained from the environment and in the preparation of which other organisms have played important rôles. The food required by non-green organisms is obtained either saprophytically from the decomposition of the remains of dead plants and animals, which have fed upon plants, or parasitically from intimate contact with a living organism. It is often considered that the parasitic or saprophytic manner of securing food is a degraded type of nutrition and that the only self-respecting method is by means of the photosynthetic process practiced by chlorophyll-bearing plants. Such heterotrophic plants are believed to be "coasting down an inclined plane of degeneracy which will ultimately result in their extinction." Certain atrophies and morphological changes associated with the parasitic habit are commonly indicated as supporting this assumption. With this point of view exception may be taken. The atrophies

found in plants associated with a dependent mode of life are, in large part, merely reductions of features which were originally developed in association with and for the purpose of aiding in the photosynthetic function. Mankind, which we in our egotism believe represents the ultimate in organic evolution, presents an excellent example of successful nutritional dependence. Furthermore, the numerous atrophies and morphological changes found in man, as compared with the lower animals, are usually not considered to represent degradation but rather to have resulted from more or less normal evolutionary changes brought about in consequence of changing environmental conditions and uses.

The term parasite is often used in a broad sense in referring to certain types of dependence among humans usually with a derogatory connotation implying an unpraiseworthy degree of laziness. This concept of parasites as representing undesirable members of human society has also, by popular usage, been applied to dependent individuals among the lower groups of organisms. This is illustrated, for example, by the following statement by one author:

> Parasitic plants indicate the length to which plant life will go in its determination to exist, but they also "point a moral" in which the examples elicit a degree of contempt. A parasite lives at the expense of another, doing no worthy labor, but always managing to propagate its degenerate kind.

When used in reference to humans the word parasite implies certain psychological, sociological, and ethical relationships quite foreign to any that are possible among organisms below the evolutionary level of mankind. The term parasite when applied to lower forms of life should always be used in a more technical sense. It should denote definite physiological, morphological, and ecological features and associations and thus possess a more exact and restricted signification. That dependence of one individual upon another is *per se* always bad and consequently undesirable would appear to be an assumption quite out of line with facts. Dependence of individuals upon each other, directly or indirectly, is a relationship which is common throughout all groups of living organisms. Whether the benefits of this relationship come from a direct physical contact or through some intermediate agency and whether the association results in injury to either of the organisms or not would seem to be insignificant distinctions when the basic nutritional aspects of the question are considered.

The world and all the things thereof may be divided into the two categories of the inorganic or non-living and the organic or carbon-containing substances characteristic of the composition of all living organisms. It appears probable that the nature of the primitive or early phases in the earth's development was wholly inorganic and that organic substances came into existence at some subsequent but as yet unknown period. It is in the realm of the organic that life primarily centers and upon which our interest is chiefly focused.

The locale of all life processes—the vehicle for the bearing of that which we recognize as life, as all students of science know—is the nearly transparent, somewhat viscid, and altogether quite unimpressive-appearing substance now known as protoplasm, which is the indispensable material of the living cells of all organisms. Protoplasm

has long been, and still remains, the object of intensive investigations concerning the nature of its chemical, physical, and biological being. Much has been discovered about it. The phenomenon of heredity, the reactions to environmental forces, and many other biological characteristics of cells are becoming common knowledge. The principal classes of chemical constituents are generally recognized at the present time. Much has been learned about the physical make-up of cell structure, although some details still remain puzzling and are the bases of various theories which lend interest to further research.

Unquestionably, the most interesting feature of protoplasm is its capacity for carrying on those reactions and adjustments which we consider to be criteria of life. It is able to grow and increase itself and to reproduce in a variety of ways. It is sensitive to the innumerable environmental stimuli which impinge upon it and is able to adjust itself favorably in response to them. That life depends for its being upon a very delicately balanced system of biological, chemical, and physical factors is obvious to any careful observer. It is a simple matter to destroy life by various suitable means. Lethal forces unquestionably bring about physical and chemical changes and upset the balance so essential for its continuance. Precisely what has occurred is problematical to a large extent. It is sometimes difficult to detect any conspicuous structural difference between a living cell and one that has been carefully killed. If one could accurately identify and correctly interpret the changes which occur during senescence and death, the nature of life itself might be revealed, and man could perhaps develop a method of duplicating protoplasm and of endowing it with vitality.

How and when life first appeared are questions seemingly not amenable to satisfactory scientific solution. Students of organic evolution are agreed, in the main, that it probably originated in a very simple, non-organized mass of protoplasmic-like material. That this original living matter did not possess the form and specialization evident even in the most primitive and simple organisms now extant would seem to be a logical inference. It could be assumed that primal protoplasm was entirely similar to that which now exists. But can such an assumption be justified? There are many requirements essential to the maintenance and continuance of life. One of the most fundamental is that there be a supply of sufficient energy. Did primitive protoplasm utilize the same specific energy sources as does its modern descendant? Processes of evolution are inherent in protoplasm itself. It is not inconceivable, therefore, that primitive protoplasm may have been able to function without the same complexity of energy requirements that we now find.

It is reasonable to conclude that primal protoplasm was necessarily endowed with the ability to grow and to reproduce itself, to nourish itself through some synthetic process, and to adjust itself in response to environmental stimuli. Whether chlorophyll originated contemporaneously with the first protoplasm or came into being at some later date is a question of considerable significance when we consider the phylogenetic relationship of the lower plants. Protoplasm, as we now

understand it, requires organic, carbon-containing compounds for food and a source of energy. Since the origin of chlorophyll, the chief source of such organic matter has been from green autotrophic plants. They are able, by the so-called photosynthetic process, to unite the carbon-dioxide of the air with water and to incorporate a part of the solar energy in the resulting carbohydrate molecules. The more complex foods such as proteins and fats are further elaborated presumably by non-photosynthetic processes through additions to and changes in these basic carbohydrates. While it is now true that practically all organic food is the product of green plants, it is, at the same time, known that a small number of fungi are able to synthesize food by utilizing energy obtained from the oxidation of inorganic compounds. Also, a few species of fungi are able to utilize solar energy and photosynthesize with pigments other than chlorophyll. These synthetic processes on the part of chlorophyll-less autophytes are now quantitatively unimportant. They are, nevertheless, of great significance when one canvasses the possible sources of foodstuffs in a hypothetical pre-chlorophyll period of organic life.

To many students of the question it appears that organic life probably existed for an indefinite period of time previous to the genesis of chlorophyll pigments. The sources from which these primitive organisms received their requisite food are not easily identified from a study of conditions now prevailing. The possibility of their dependence upon chemosynthesis or photosynthesis with non-chlorophyll pigments appears to be an inviting and plausible theory, inasmuch as these processes are both operative in some of our most primitive non-green plants of today. Unfortunately, it is impossible to obtain any definite knowledge of the physiology of primitive protoplasm. It seems reasonable, however, to assume that even in the pre-chlorophyll age at least some individuals must of necessity have possessed a synthetic process and that others at the same time undoubtedly acquired the ability of utilizing the products of such autotrophic species in a parasitic or saprophytic manner.

The origin of chlorophyll and its introduction into the cell structure and its utilization in the production of elementary, energy-carrying foods had an extremely great and far-reaching influence upon the evolutionary process. Organisms which until this time, according to the opinion of some, had been progressing along a more or less common highway of evolution became differentiated into the great plant and animal kingdoms. Evolutionary advance now proceeded along two progressively diverging lines of development, with green plants destined to become the manufacturers of foods for virtually all organisms lacking such pigmentation. The distinction is sometimes made between plants and animals to the effect that plants make food and animals do not. This differentiation is, of course, superficial and misleading when one considers the great numbers of plants which are as dependent upon outside sources for their foods as are animals.

Division of labor in unicellular organisms is obviously impossible, and, consequently, the single cell is required to carry on all of the physiological processes essential to the maintenance of its life and reproduction. One of the early stages in the evolutionary development of living organisms was the grouping of a number of cells into a colonial

association. In many such colonial arrangements each cell apparently carries on its functions as completely as though it were wholly separate. Eventually, however, some cells became specialized for the purpose of doing work for the common good of the cell group, and we have then not a colony but a simple multicellular organism.

Chlorophyll is generally present in all or nearly all of the cells of primitive plants. As evolution progressed, however, plants became increasingly more complex with the photosynthetic function more and more restricted to special chlorophyll-bearing cells. One of the results of the specialization of the photosynthetic process is apparent in its effect upon the morphology of the plant. Leaf or leaf-like structures definitely designed to facilitate photosynthesis are a prominent feature of nearly all of our higher plants and are lacking only in the more primitive groups or in plants over which certain environmental forces have become dominant.

In the physiology of nutrition, if we except the synthetic processes, each cell of an organism acts essentially as though it were a separate unit. Materials entering any cell must first be rendered soluble before they are able to pass through the protoplasmic membranes, regardless of the phylogenetic position of the organism. The entrance of materials into the cell of any simple organism is believed to obey basic physical and chemical requirements similar to those necessary for their passage into any of the living cells of our most complex multicellular organisms. This appears to be true whether the movement be from outside the plant, as from the soil into the roots, or between adjacent cells within a tissue. The distinction commonly made between saprophytism and parasitism lies not in differences of food substances nor in the manner of acquiring them but solely on the basis of whether the food is obtained directly from an organism that is alive or from a non-living source. No organism is capable of utilizing and incorporating living substance into its own body. It would appear, therefore, that all foods are necessarily inanimate when they enter a cell. When organic material is taken from a living source there results in most cases a harmful or at least a detrimental effect on the host, inasmuch as it loses substances which were destined for use in the physiology of its own cells. The relationship which exists between the chlorophyll-containing cells of multicellular organisms and those which are colorless is similar in many respects to that prevailing between the host and its parasite. The colorless cells are as dependent upon their photosynthetic neighbors for basic carbohydrates as is a parasite upon its host. In this relationship, however, the nutritional balance between the various units is maintained in such a manner that the green host-cells apparently are not injuriously affected to any extent.

It is not uncommon to find two or more species of algae living in close association. It appears possible that under suitable conditions one of the species might obtain some food from its associates in a manner somewhat comparable to that in which the non-green cells of higher plants obtain theirs. Such food transfer might involve slightly different physical factors, but it would not, seemingly, need to differ materially from an exchange between the closely associated cells of an algal colony

or between the green and non-green cells of a multicellular plant. The development of the simple haustoria exhibited by species of fungi would not appear to present any difficult evolutionary problem.

Fungi have developed along evolutionary lines quite distinct from those of their algal relatives. They are able to thrive in environments and under conditions impossible for green plants. This variation of habitat, as well as other factors, has probably played an important rôle in influencing the development of the reproductive habits and other characteristics peculiar to the various fungal groups. It is probable that parasitism appeared very early in the evolutionary development of living organisms. When once established as a specific characteristic, it has persisted and become amplified in succeeding groups. The study of evidences of pathology in fossilized plant and animal remains is interesting in itself but would not appear to throw much light on the origin of parasitism. There can be no sharp lines of difference drawn between parasitism and saprophytism, and the question as to which is more primitive does not seem to be significant. A number of dependent organisms are known which are able to adjust themselves either to a parasitic or to a saprophytic mode of existence as conditions demand, and it seems reasonable to assume that the earliest forms of dependence may have been as readily facultative.

Interesting examples of parasitical relationship are those existing between the gametophytic and the sporophytic generations of plants exhibiting alternation of generations. In general, the gametophyte of the lower plants bears chlorophyll and supplies a more or less dependent sporophyte with its necessary food. This nutritional dependence on the part of the sporophyte is illustrated by many bryophytes. In this group the sporophyte usually lacks chlorophyll and is commonly attached to a more prominent and photosynthesizing gametophyte by a haustorium-like structure called the "foot." The sporophytes develop chlorophyll and assume a degree of nutritional independence among some of the higher bryophytes, but all remain dependent to some extent for at least their water and mineral requirements. In the pteridophytes a complete reversal of sporophytic and gametophytic relationship occurs with the sporophyte becoming the dominant phase. While it apparently never becomes completely independent of the gametophyte for at least some of its food, especially in its early stages of development, it does assume at maturity the dominant rôle in food production for those plants evolutionarily superior to the bryophytes. The gametophytes of ferns appear to be nutritionally independent of the sporophytes. Among other members of the pteridophytes, however, there is a definite tendency towards the loss of the photosynthesizing function and the necessity of obtaining food from some external source. Some of the gametophytes of Lycopodium, for example, have no chlorophyll and must depend for their foods largely upon the activity of the mycorrhizal fungi with which they are invested. Among the seed plants the gametophyte remains wholly dependent upon the sporophyte. There appears to be little or no fundamental distinction, so far as nutritional factors are concerned, between the sporophyte-gametophyte relationship of many plants and that existing between a typical parasite and its host. It may not prove unprofitable

to seek answers for some of the questions involving parasitism in this field of inter-generation relationship.

It might naturally be expected that an innovation as significant as the introduction of chlorophyll into the structural and physiological make-up of cells and the advantageous photosynthetic activity resulting would become permanent features. It would appear, also, that the food problems of chlorophyll-containing organisms would be largely solved, or at least greatly minimized, by the development of the photosynthetic process and that such organisms would be reluctant to discard this apparently easy way to nutritional independence. Since its inception, chlorophyll, however, has not remained a constant characteristic of all plants possessing it, and there are many species in which it has been partially or wholly eliminated. As previously stated, the photosynthetic function is common to all or nearly all of the cells of the more simple and primitive autophytic species. However, as plants developed greater complexity and division of labor became more emphasized, the chlorophyll-bearing cells became more and more segregated. Many tissues completely lost their ability to photosynthesize and consequently were dependent upon their chlorophyll-bearing associates. Furthermore, there are numerous species distributed throughout the plant kingdom which have developed the ability of securing some or all of their food requirements from a source external to themselves. Why plants which presumably possessed chlorophyll and, hence, nutritional independence should develop some other seemingly more precarious means of securing their food is one of the interesting problems of biology. On the other hand, whenever the parasitic mode of life has been adopted, it has commonly persisted and become a permanent feature in the life of the species. There is no evidence of the abandonment of the parasitic habit after it has been once initiated. The introduction of the parasitic habit ordinarily provokes a number of morphological changes, particularly in those structures associated with photosynthesis. The chlorophyll gradually disappears, the leaves are reduced, and normal roots are sometimes replaced by haustoria.

The largest and most notable group of dependent plants is the cosmopolitan aggregation known as fungi, which is one of the most important groups of plants when considered from an economic point of view. They are comparatively simple morphologically and are believed by many to represent chlorophyll-less descendants of autophytic algal ancestors. In no other group of organisms, aside from animals, has the dependent mode of life become so prominent and well established. That their loss of independence is not seriously disadvantageous is evidenced by the large number of species and their very obvious success in competition with autophytic plants. An interesting fact, which may have some significance when considering the phylogenetic relationship of fungi, is that several species of algae have been reported as able to supplement their photosynthate by absorbing organic substances from their environment. This might be interpreted as indicating a preliminary step in the establishment of a dependent mode of nutrition. As one would expect in a large and diverse group such as the fungi, there is to be found practically every conceivable variation in nutritional re-

lationship, ranging from obligate parasitism on the one hand through various degrees of facultatism to obligate saprophytism on the other.

Parasites are commonly looked upon as being injurious to the hosts upon which they grow. There are, however, many parasite-host relationships in which the host is obviously not seriously affected and not infrequently is actually benefited by the association. The legume-nitrogen-fixing bacteria combination, the numerous mycorrhizal relationships, and many other examples illustrate such beneficial alliances. The large number of autophytic species now known to harbor mycorrhizal fungi is indicative of the advantage of this combination in which often both the fungus and the host are believed to be beneficiaries. Some higher plants have developed a dependency upon their mycorrhizal confederates to such a degree that it is difficult or impossible for them to thrive in the absence of the fungus. The fungus in such cases acts as an intermediate agent by assisting in the preparation and absorption of food substances from the soil for later utilization by the host. In Calluna, the Scotch heather, the mycorrhizal fungus grows abundantly in and upon the roots and may even penetrate to other parts of the plant. The heather does not thrive in the absence of the fungus, which is reported as having the ability to fix nitrogen. In the presence of an abundance of soil nitrogen, however, the fungus may become too aggressive and destroy its host. Study of the interrelation of fungus and host in cases such as the heather illustrates the complexity of the relationship and the delicacy of the balance which often exists between two such organisms. Monotropa, or Indian Pipe, long considered to be a rare example of a flowering plant living saprophytically upon decomposing organic matter, is now known to have its roots invested by a mycorrhiza. It is, therefore, to be considered more as a parasite upon these root fungi than as an example of a saprophyte. Thus, we have an illustration of a curious and anomalous situation where a higher plant becomes parasitic upon a fungus.

With the exception of mycorrhizal fungi and the inter-generation dependence, we find parasitism almost entirely limited to fungi and to certain flowering plants. It is exceedingly rare or lacking in the groups including the mosses and the ferns. Among the numerous parasitic species of flowering plants the variations exhibit every conceivable combination of interrelationship and dependence. The mistletoes of the family Loranthaceae contain chlorophyll and are dependent upon their hosts only for water and minerals. Such so-called "water parasites" represent, in the opinion of some, an early phase in the evolutionary development of the parasite which will eventually acquire the ability to absorb elaborated foods, lose its chlorophyll, and thus become completely parasitic. In the Scrophulariaceae or figwort family there are a number of species parasitic or partially parasitic upon the roots of other plants. Many of the genera are independent, but, on the other hand, species of Lathraea, for example, are completely parasitic. Species of Pedicularis are parasitic to a slight degree; those of the genus Tozzia live for part of their lives as complete parasites but eventually produce a chlorophyll-bearing aerial shoot and hence become partially independent. Selection of proper examples in this family gives a series of species illustrating

a gradual transition from complete independence to complete parasitism.

In the genus Cassytha of the Lauraceae and Cuscuta of the Convolvulaceae we have examples of comparable evolutionary development in which the parasites become attached by haustoria to the aerial stems of their hosts. It is interesting to note the similarity in habit of growth and development of the species of these two quite unrelated genera. It is not unusual for specimens of Cassytha to be mistaken for the more common Cuscuta or dodder. Cuscuta is an example of complete parasitism and extreme morphological modification because of its nutritional dependence. Chlorophyll is present to some extent in the stems and flowers of certain species but for the most part it is lacking; the leaves are reduced to small, inconspicuous scales, and normal roots never develop. The embryo is slender and coiled about within the seed. Upon emergence one end becomes erect and assumes the attitude of a snake in a striking position. This erect portion describes circumnutation movements which upon contacting a suitable host enable it to coil about the plant. Haustoria soon develop in the region of the coils and the parasite thus becomes firmly attached. There may be traces of chlorophyll in the seedlings of some species, but, nevertheless, if they do not soon reach a host, they perish. An interesting form of self-parasitism in the dodder has been described as occurring during the seedling stage. It has been shown that the seedling, in a few species at least, is able to elongate at the erect or anterior end and thus increase to some extent its range of search for a host by transferring and utilizing food material obtained by digestion of the posterior portion. There are many additional species of flowering plants which, likewise, show parasitical habits to a greater or lesser degree. Many of these are of considerable interest.

Many interesting problems are found in the relationships existing between parasites and their hosts. There are varying degrees of host specialization shown by different parasites and also defensive reactions on the part of some host plants which might in some cases be interpreted as a form of immunity. It is difficult to imagine an immunity in plants involving antibody formation comparable to that developed in animals. An explanation of many of the selective or antagonistic relationships is, for the most part, however, to be sought in differences in structural and chemical features and also in the osmotic dissimiliarity of the host and parasite cells. It has been demonstrated in certain cases that the osmotic concentration of the cell sap of the parasite is necessarily higher than that of its host, and, unless this condition can be satisfied, it is impossible for the parasite to obtain material from the plant upon which it is growing.

Thus, as we survey the plant kingdom, we observe innumerable examples of nutritional dependence. In fact, dependence to at least some degree would appear to be much more common than is generally supposed. The use of the term independent in connection wtih chlorophyll-containing plants is purely relative. No organism can be said to be wholly independent and live in a state of "splendid isolation" from other organisms. It is true that green plants are able to synthesize carbon-containing compounds. It is equally true, however, that they are dependent for a number of their requirements upon the activities of or-

ganisms which inhabit the soil and which help prepare the various elements needed for the physiology of the green plant. These soil organisms, of course, are in turn largely dependent upon the compounds produced by the green plant which are made available when it dies and returns to the soil and is acted upon by the "wrecking crew" of soil microorganisms.

The various forms of parasitism, saprophytism, symbiosis, and mycorrhizal relationships are but variations of processes between which there is no obvious or definite line of demarcation. The gradations between mycorrhizal and various symbiotic relationships are slight, as are, also, those differentiating between typical parasitism and saprophytism. It is, likewise, difficult to distinguish between a true symbiosis and the various shades of relationship known as commensalism, helotism, etc. It appears obvious that these are but variations of the same theme with slight advantages in favor of one or the other of the organisms involved. The interrelationship of organisms often depends upon a finely balanced system of factors, and, when one or more of them are altered, the relationship may be definitely changed.

The circumstances which prompt a self-nourishing plant to assume a dependent mode of life are not conspicuous. That they have been frequently operative, however, is evidenced by the numerous examples of dependent species believed to be descendants from chlorophyll-containing ancestors. It is commonly assumed that an organism which obtains its food by parasitism rather than in an autophytic manner is degenerate. The successful manner in which parasites are able to maintain themselves in a highly competitive relationship, however, casts some doubt upon this assumption. Whether parasitism represents an occasional example of retrogressive evolution, as is popularly thought, or is, perhaps, a more general condition throughout all groups of living organisms, or even representative of progressive evolution, is a question which might well be raised. Why is any successful method of securing food by plants to be considered contemptible and degenerate? The evolutionary substitution of one process or structure for another would not necessarily indicate degeneracy if such changes do not impair the ability of the organism to maintain life successfully and to reproduce. Does the evolutionary change increase the organism's capacity to live successfully and survive? This is a question which might be asked when deciding whether the direction of evolution is progressive or retrogressive. The almost limitless number of examples of nutritional interdependence of every degree would lead one to the conclusion that such dependence, which we may term parasitism in a broad sense, is to be considered in plants at least a more or less normal way of life.

# ARCHEOLOGY

Chairman: PAUL WEER, Indiana Historical Society

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The program of the section on archeology and the attendance at the meeting indicated a sustained interest in this field.

A significant part of the program was centered around the progress which is being made in the excavation of the Angel Mounds east of Evansville, under the direction of Glenn A. Black. This great mound group and habitation site, probably the most imposing of all prehistoric remains in Indiana, was recently purchased by the Indiana Historical Society in order that a scientific study of it could be made and its relationships to other great remains in the eastern part of the United States be determined.

The program also presented some aspects of the study now being made of the "Walam Olum," a famous Indian document believed to have been procured from the Delaware Indians living along White River, in Indiana, in 1820, and, passing from a "Dr. Ward, late of Indiana," to have fallen into the hands of Constantine Samuel Rafinesque, then a professor at Transylvania College, Lexington, Kentucky. Accounts of the "Walam Olum" were published by Rafinesque in 1836, by E. G. Squier in 1848, and by Daniel Brinton in 1885.

A paper by Dr. Thomas B. Noble, Jr., on Art and Archeology, in which he discussed some phases of his latest trip to the prehistoric Southwest, was presented with colored slides.

Paul Weer, Indiana Historical Society, was re-elected chairman of the section for 1940.

# The Problem of the Atlatl

E. Y. Guernsey, Bedford

The "atlatl," or "throwing stick," is a simple but ingenious implement by means of which a light lance or spear may be cast with greater velocity and precision than would be possible through the use of the hand and arm alone. It provides, in effect, an extra extension of the arm and an additional lever or toggle-joint by means of which combination the propulsive force applied to the spearshaft is greatly increased. It should be considered as a weapon, being in fact a sort of counterpart of the bow.

Objection may be properly raised against the use of the word "atlatl" to apply in general to this weapon in use since remote times in some quarters of the six continents and the islands of the several seas. In Australia it is called a "wommera," and in each region where it is used it bears a different name.

To call it a "throwing stick" is likewise objectionable since the "boomerang," a "stick" which is itself thrown, is also defined as a "throwing stick." Krause, a reliable authority upon the spear thrower, raises these objections but ends by calling the weapon in all of its forms a "spear sling"—which suggests, to us at least, a use of thongs or cord, as in the ancient Greek "amentata." The French archeologists, who call it, quaintly, a "propulseur," perhaps come more closely to hitting the mark and providing a really appropriate name for the implement.

What we have here to say comprises, we admit, no more than a brief and insufficient digest of the prolific literature upon the spear thrower as it has been and is now still used in various parts of the world. The two or three years devoted to its study have convinced us that we have, at best, merely scratched the surface of an intriguing field for research. Experiments in its actual use have created an unbounded respect for the versatility of this primitive implement and have provided a decidedly better understanding of its perquisites and possibilities.

The problems of the "atlatl," which are many and varied, may start perhaps with that of the ultimate discovery of its common original source. Its religious, totemic, and ceremonial significances provide another bypath, for primitive man in the most diverse times and places has consistently carved, painted, and adorned it with the symbols of his religious belief or has affixed to it the numerous "charms," "totems," and similar devices, which are presumed to insure success in the chase or in war. Upon Paleolithic examples from France certain incised "tally marks" are presumed to have indicated the number of victims of the spear thrower. In Australia, Eskimoland, and elsewhere a very natural phallic significance is often observable in its form and decoration. Mexican "atlatls," which have come from Mixtec, are so elaborately

carved, painted, inlaid, and gilded as to imply that they were not intended for actual or practical use.

After all, however, our own somewhat extensive research suggests that in basic construction and design there is no considerable difference in the spear thrower wherever it is found. The Australian implement is very like that of Boreal peoples, and specimens from Greenland are sometimes so similar to those of Tierra del Fuego, even to their thonged handles, that it would be difficult to tell them apart.

Since the discovery (1915-1916) by Moore of the unusual culture complex manifested at his Indian Knoll site on Green River, Kentucky, the problem of the "atlatl" has been brought into our own archeological field. Since then Fowke has investigated a similar site at the mouth of Town Creek in northwest Alabama; we have ourselves found a considerable occupation of the same group about the Falls of the Ohio. Webb has explored sites of similar character in the vicinity of Town Creek on the Tennessee River, and Webb and Haag have revisited the region of Green River, partially explored by Moore earlier. We have recited the various extensions to the Indian Knoll occupation in the chronologic order of their observance, which is after all unimportant.

Quite recently, Webb has concluded that certain hook-like objects of antler, customarily associated with rectangular or "reel shaped" so-called "bannerstones" of stone or bone in burials of this culture pattern, comprised, respectively, the distal ends of "atlatls" and weights attached to their shafts. Not only does he so conclude, but he appears likewise convinced that this discovery provides "a new common trait between this Indian Knoll culture pattern and that of Basket Maker II of the Southwest."

One of our own major problems has been, as has been true with others who have studied this manifestation, a determination of the use or purpose of these artifacts, an objective which is, in our opinion, still unaccomplished.

In an investigation of Basket Maker II sites in northeastern Arizona, Guernsey and Kidder recovered a number of "atlatls" of ancient Mexican type, also distributed through Central and South America and even in Florida. A feature of this "atlatl" form, as they reported, was the customary attachment of polished stone or chipped flint, fossils, seeds, or nuts to its shaft by ligature or wrapping of objects. The smallest of these objects reported was 1 inch in length; the largest, 2⅜ inches, weighing 2 ounces. In describing these objects, Guernsey states that, since no practical use could be imagined for them, he could think of them only as charms. The authority Krause classes similar objects attached to "atlatls" as "luck stones." In general, these objects of stone, bone, or flint are flattened upon the surface of attachment and range from ⅛ to ¾ inches in thickness. It is apparently largely upon the basis of the inclusion of objects of this character with the Mexican "atlatl" that Webb has drawn his conclusions and reconstructed a number of problematic implements incorporating the hook and bannerstone characteristic of the Indian Knoll culture pattern. In his report upon the Chiggerville (Kentucky) site he states that "these stones [of the Arizona sites] were securely attached to the throwing stick and

are designated 'weights' in the belief that they served to give balance to the instrument, and to increase its power in projecting the shaft when thrown." Referring to Guernsey's report, wherein two tabular "atlatl stones" or 2 and 2⅛ inches length, respectively, are illustrated, Webb includes as "atlatl" weights a much larger and heavier artifact found typically at Chiggerville and our own Ohio Falls sites. These artifacts, as they appear at Ohio Falls, are often 6 inches in length, and those figured by Webb are apparently of like size.

It is our own opinion, based upon evidence which we believe is substantial, that the movement of Indian Knoll peoples was southwestward and that the several occupational "stations" of the group extending from the Falls of the Ohio to northwest Alabama mark a progressive cultural decline. This is doubtless at variance with Webb's belief, as we interpret it, that the "atlatl" was introduced to Indian Knoll peoples by way of the region of Basket Maker II. Certain it is, in any case, that the Ohio Falls sites, embracing numerous related villages long occupied and densely populated, represent the most impressive concentration of this group so far observed. In addition, it is appropriate to point out that within this area the typical artifacts are superior in design and workmanship to those found elsewhere.

It was possible, at Ohio Falls, to account quite definitely for a successive occupation of the identical sites by a group of southern origin and a still later occupation by a second southern group considerably more advanced in culture. What happened to the original occupants of the site is, we suspect, involved with the appearance and removal of one or the other of these southern sojourners.

Although Moore makes no mention of it, it seems to us obvious that his Indian Knoll site includes, also, a secondary occupation. That this is patently true of Fowke's Town Creek site and those of Webb in the same region we feel certain.

In Moore's report upon Indian Knoll he submits the theory, upon which he was apparently not quite convinced, that the typical bone hook and accompanying bannerstones served respectively as crochet hooks and gauges or "spacers" used in conjunction in the fabrication of nets. Willoughby, whom Moore consulted, did not believe they were so used; nor did he believe that the hooks might have been the distal ends of "throwing sticks." Moore agrees with the latter conclusion and submits the following reasons for this assumption:

1. That the throwing stick or positive evidence of its use has not been found anywhere in the region in which is "The Indian Knoll."

2. That nearly all throwing sticks are of one piece, a construction that insures the required strength.

3. That small points of antler or of flint, which might have served as tips of the shafts used with "atlatls," were not found associated with his discoveries.

4. That some of his hooked implements were too crooked to have been used on throwing sticks and that the cavities in some were too inconsiderable to have served for the insertion of the main part of the "atlatl."

5. That the assumption that the hooked implements were parts

of "atlatls" offers no explanation in regard to the large objects of stone and antler found with the hooked implements and indubitably connected with them.

Concerning Moore's argument in general as it might apply to the Ohio Falls region with which we are most familiar, we have nothing controversial to offer except that at his own Indian Knoll site and at those of Fowke and Webb upon Tennessee River, crude hooked implements appear which might have served very practically as adjuncts of the spear thrower. In the region of Ohio Falls the hooks are consistently of a single pattern with delicately barbed ends which appear too fragile to have served as "atlatl" hooks and with their angular projections unfractured. It is true that leaf-shaped lanceheads of flint, these often 5 inches long, appear so abundantly as to suggest that the lance was used almost exclusively. So heavy were these points, however, that they must have been lashed directly to a shaft too heavy to have been propelled by the spear thrower. The bannerstones in this region are predominantly of polished stone, differing from those of Indian Knoll only, perhaps, in that many have concave ends and a few bear transverse ridges about their extremities. Those of bone are in this region most infrequent. There are here no round grave burials, there is no copper, there are no pipes, and it is probable that the few bits of pottery recovered pertain to a secondary occupation. Artifacts, including those of both stone and bone, are consistently carefully fabricated.

At Indian Knoll, on the other hand, copper appears. Round graves are typical, stone work (except in the case of bannerstones) is inferior, pipes are probably absent, and there is perhaps little pottery. Wyandotte hornstone, absent at Ohio Falls, probably supplies the bulk of material used in projectiles. The typical Ohio Falls lancehead is present but is in the way of being supplanted by notched or stemmed arrowpoints. As we have suggested, there is here a considerable diversity in the form and length of the bone hooks, many appearing too clumsy to serve as a competent implement for delicate textile work.

In connection with Indian Knoll, it is appropriate to introduce at this point a principal argument, or so we believe it to be, against the "atlatl" theory. This takes in the findings of Neumann upon an examination of the available skeletal material from Indian Knoll with which the typical bone hook and bannerstones were found associated. Out of a total of 31 burials reported by Moore with such association, the skeletal remains of only 17 were available for study. Of these Neumann found that: 4 represented adult males; 3 represented adult females; 4 represented adolescents; 6 represented children.

Of the remaining skeletons, one was reported by Moore as a child, leaving 13 adult subjects unaccounted for, some of which were doubtless females. The point to be considered is, of course, that it would be a reversal of aboriginal custom to include the weapons of a man, such as the "atlatl," so generally with burials of female and juvenile subjects. A similar situation prevailed at Ohio Falls, in that three bannerstones were found within the pelvic basin of a female subject, and these objects were likewise included with other female burials. At these sites, however, burials of children were confined to a separate quarter,

and neither of the objects in question was found in association with such burials.

As reported by Webb, Site Lu°86, many of the traits typical of Indian Knoll were found to persist in his northwest Alabama site, this quite near the Town Creek site of Fowke. He observes that there were here low, fully extended burials, 13 flexed burials, and 6 bundle burials. The typical lance point still appears; one "spear thrower of bone," only, is mentioned, but it is assumed that others made of wood had disappeared through decay. There were, however, no bannerstones, either of stone or bone, such as appear so abundantly at Indian Knoll and Ohio Falls. The suggestion that pointed bone fragments cut from the cannon bone of the deer, here quite numerous, served as projectile points, he believes is strengthened by finding many of them fractured and battered at the heavy end as if by impact. These objects, which appear both at Indian Knoll and Ohio Falls, are, we believe, typical of the Indian Knoll culture pattern, as well as are numerous other artifacts he describes from this site.

Of Fowke's Town Creek site, it may be said that the same pattern may be recognized, even if but feebly expressed. There are here numerous flint implements, mostly spearheads and knives, three short and eccentrically shaped bone hooks, bone awls similar to those found at the northern sites, and the projectile point of deer metapodial described by Webb. Here, however, as at Webb's nearby site, there are no bannerstones. At both of the Alabama sites the picture is one of a material culture at its lowest ebb. Fowke, in his customary fashion, asserts stoutly that there were numerous evidences of cannibalism manifest at the Alabama site he describes, and the proof he supplies seems to us sufficiently convincing.

In a paper whose reading is confined to ten minutes it is, of course, impossible to do more than faintly suggest the importance of pursuing the "atlatl" theory to its ultimate lair before the desirable, essential conclusions are submitted. For ourselves, we are yet in the situation of indecision. It does appear to us, however, that there are legitimate reasons for assuming that the assumption that the Indian Knoll hook and bannerstone are to be considered perforce as inseparable in function and purpose is erroneous. In detail we have examined, time and time again, authentic collections in museums here and there in which the veritable Indian Knoll bannerstone is recorded as from Massachusetts, New Jersey, Pennsylvania, Virginia, West Virginia, Ohio, Kentucky, Indiana, Missouri, Tennessee, Georgia, North Carolina, South Carolina, Florida, Oklahoma, and even from Michigan, Wisconsin, and Ontario. We have pursued it, at all events, as near the Mexican frontier as Oklahoma, but, unfortunately, it has led us also into Canada. Meanwhile, we have been unable to follow the antler hook beyond its restricted habitat within the boundaries of the region assigned to the pattern of Indian Knoll.

# Report on Progress at Angel Mounds During 1939

Glenn A. Black, Indiana Historical Society

A preliminary report of progress during one of the several seasons required for the completion of a large archeological project must obviously be an inventory rather than a cultural synthesis. The Angel Mounds Site proving the rule rather than an exception, the following is a catalogue of pertinent data revealed by the first year's investigations.

Accurate surveying has substantiated early reports of features long ago erased from view by cultivation. Aerial photography has also contributed much toward a review of these features.

Excavation has proceeded successfully with gain counted by specimens and much data, equally valuable even if less tangible.

Ceramics, especially, point to an affinity with tribes living far to the south and southeast. Physical types, as represented in skeletal material, bear out the lead provided by pottery.

House sites, with remnants of the clay daub used for plastering the walls together and with fireplaces and small cache pits filled with maize, maize cobs, nuts, and seeds, provide an insight to a personal phase of aboriginal life in southern Indiana.

Charcoal found in the excavations has been recovered, treated, and stored with the hope that by dendrochronology it may be made to provide dates for occupancy of the village.

Although conclusions at this stage of the investigation are out of the question, it seems justifiable to state that Angel Mounds will be one of the most prolific village sites in the state; that the occupants carried with them a culture at least reminiscent of tribes in the southeast and Gulf States region; that the occupants were agricultural, highly sedentary, and animated by the accomplishments that go with permanency; that Angel Site was the center of government from which civil, economic, and religious decrees radiated to a community of sites, many of which have been found on the river terraces nearby.

# Ethnological Notes on the Ottawa

Paul Weer, Indiana Historical Society

Ottawa Indians, members of the Algonquian linguistic stock, were not overly interested in vacating their Michigan lands and moving onto reservations in Kansas as stipulated by treaties of the period 1830-1840. Fortunately, the white man did not insist; so for two hundred years and more the Ottawas have continued to inhabit the northwestern areas of Michigan's lower peninsula. In Emmet, Charlevoix, and Antrim counties, and trailing off into contiguous counties, these people have remained, in the midst of their incoming white neighbors, as fishermen and trappers, as small farmers, humble tradesmen, and as laborers in the lumber enterprises of this region. Since the lumber camps and saw mills and shipping docks of a generation ago have faded out with the final cutting down of the great pine forests, the Ottawa population has gradually dwindled. Middle Village, once the largest center of Ottawa life in the midst of numerous smaller habitation sites strung along the Lake Michigan shore in Emmet county, is now only a deserted village. The late generation is filtering out into new localities, but, here and there, notably at Cross Village and Harbor Springs, a semblance of village communal life is still to be found.

According to their own traditions, Indians in this territory must be "counted three layers deep," as they express it. First, long ago—they know not when—there were Indians here—they know not whom. Second, again there were Indians of whom the Ottawas remember nothing. Then, third, and last, came the Ottawas. That, they say, was about two hundred years ago, and then they had everything they have now in the way of living. They have always, they affirm, been poor farmers, made no pottery and only the most simple and crude stone, bone, and flint artifacts. They possessed no copper except that which an occasional individual carried as a charm made of that metal. Father Allouez saw a group of Ottawas blowing smoke into a bronze (?) image a foot high, an article which he recognized as an importation. Is it possible that most of the copper artifacts found on the surface in northern Michigan and Wisconsin (and the vast majority of these have been surface finds) were made after the coming of the French? Quoting from the Jesuit Relations: "Among the donnés and the Jesuit brothers were skillful workers in metal, who repaired guns and utensils of the natives, and taught them how best to obtain and reduce the ore from lead and copper deposits. We have evidence that the copper region of Lake Superior was at times resorted to by the lay followers and their Indian attendants to obtain material for crucifixes and for medals which the missionaries gave to converts" (1, 1:33-34).

The first recorded European contact with the Ottawas is credited to Champlain in 1615 when he met three hundred men of this tribe near the mouth of the French river on Georgian Bay (2, 2:167). These he called "Cheueux relevez," "men of the raised hair," because, to quote

two later sources from the Jesuit fathers, "their hair does not hang down, but is made to stand erect like a high crest" (1, 14:99, 41:77). Champlain reported that their weapons were the bow and arrow, a club, and shield of boiled leather; their bodies were much tattooed in many fashions and designs; their faces were painted in flaming colors; their noses were pierced; their ears were bordered with trinkets. The chief made Champlain understand that they had come to that place to dry huckleberries to be used in winter when nothing else was available (2, 2:168). Even to this day in the months of July and August the hills in these areas of northern Michigan and Ontario are covered with huckleberries.

In the following year Champlain's visit to some of their villages led to his observations that the Ottawa was a populous tribe and that their men were great warriors, hunters, and fishermen, governed by many chiefs, each ruling in his own district. He also observed that they were great tradesmen, sometimes traveling in pursuit of this vocation as far as 1200 to 1500 miles. He said that the women planted corn and other foodstuffs. The women had their bodies covered, but the men wore nothing except in winter when they usually threw a fur robe around their shoulders like a mantle. He committed himself to the effect that the women lived very well with their husbands (2, 2:168).

The shores of Georgian Bay and Manitoulin Island to the northwest are credited by early white contacts to have been the Ottawa country. Traditionally, the Ottawas, Chippewas, and Potawatomis were "three fires," which, in the most ancient days, were one—a single people dwelling around one great "fire" somewhere in the north, that is, in Canada. Furthermore, tradition states that the Ottawas and Potawatomis divided from the Chippewa at Mackinaw City. The earliest known habitat of the Potawatomi was in the present northeastern counties of Michigan's lower peninsula (2, 2:289). This suggests the possibility that, when first the Potawatomis and Ottawas left their Chippewa kinsmen, both groups, probably as one people, crossed the straits southward *via* Mackinac Island to the lower peninsula and that the group, later to be known as Potawatomis, chose the northeastern territory along the west shore of Lake Huron. The groups who became historically known as Ottawas took the northwest area around Big and Little Traverse Bays on the east shore of Lake Michigan before journeying to their historic seats as of 1615 *et seq.*

This thought is not apparent within itself but is now suggested, that is, that the Ottawas were resident in Michigan's northwestern lower peninsula before going east and north to their first historically observed seats around Georgian Bay and Manitoulin Island. Certain Ottawa legends which I heard last summer from one of the best informed members of this tribe confirm this[1] and, furthermore, suggest the probability that one of the lower "layers" here may have been their own ancestors.

When Champlain first met the Ottawas on Georgian Bay, he credited them with growing their own corn. But the Emmet county Ottawas of today have a tradition of journeying to Manitoulin from the lower

[1]Joe Ettawegeshik, Harbor Springs, Michigan.

peninsula and also retain a tribal legend of how first, in this same lower peninsula country, they were directed to use the gift of corn.

They say the Ottawas went to Manitoulin because a bad Midu caused them much trouble when they were living at Houghton Lake, which is about 100 miles south of Little Traverse Bay. This bad Midu stole an infant sunning in its cradle, but, because of a charm, no one knew for several days that the baby had been spirited away. When the time came that they were to know about it, the people heard a crying a long way off. Following the sound over to the west side of the lake, they heard the cry getting louder and louder; finally they came to a tunnel. They went into this tunnel and there were the baby's cries! But, as they went farther, the cries did not come any closer because the bad Midu was digging as fast as they were coming. Then the Ottawas went back to the opening of the tunnel and hung over it a virgin's dress so that the bad Midu could not come out that way. The leaders went around to the other side of the hill and tunneled in from there toward the crying and got the infant. But the people were still afraid for their children in that bad place; so they went eastward to the shore, near the place Port Huron is now located, and from there went to Manitoulin and spread over their new lands. All of this vast territory northwest of the Huron lands was first called by the French the country of the Ottawas; the first Jesuit mission founded in all that country at Sault Ste. Marie in 1641 was called the Ottawa Mission.

The tale of the gift of corn is as follows: One fall the Ottawas departed from Wequadonzing, Little Harbor, to go south into warmer lands to hunt. They kept going until they came to Sleeping Bear, which is a high hill near the present city of Frankfort, approximately 120 miles south of Little Traverse Bay. After camp had been made for the night and everyone was resting, the young hunters heard a scratching noise on the hill. Thinking it the sound of enemies, they went up there but could find nothing that might have made the noise. When everyone was again resting in camp, the scratching noise came down as before; once more the young men went towards the sound but saw nothing except some little stalks waving in the breeze. Again they went back to their sleeping, and again they heard a scratching. For the third time they went in search of the makers of the noise, and, very carefully coming toward the sound, they discovered it was the little stalks scratching their sides for them to hear. The young warriors pulled these up and returned with them to the Sagima, the medicine man. Next night the Sagima had a dream, and on the following day, when the warriors, hunters, and all who were following with them had assembled, he said that these little stalks that had called to them were saying "mindamin," corn. From these he kept the seeds, which were all put in the ground the next year; these grew more "mindamin" which was then divided among all the Ottawa families, some to be saved for growing but the most part to be used for their eating. And so, the legend says the Ottawas had corn before they went to Manitoulin.

The Jesuit Relations of 1662-1664 recounting Father René Menard's labors among the Ottawa, says: "corn and bread are entirely unknown in those countries" (1, 48:119). And in the same narrative: "In this

country there is wild rice" (1, 48:123). This does not mean that corn was then unknown to the Ottawas, for it refers to a time when they and their neighbors, the Hurons, having been driven out of their lands in the proximity of Georgian Bay and Manitoulin Island by the Iroquois, were dwelling in northern Wisconsin, a native habitat for wild rice. Here, evidently, life had become too complicated to include corn planting! In the year 1665 Father Allouez founded his mission for them at La Pointe, on Chequamegon Bay, on the south shore of Lake Superior. Father Marquette succeeded Allouez at La Pointe in 1669. Shortly thereafter the Ottawas and Hurons incurred the hostility of the Sioux, who drove them eastward like so many leaves before an autumn blast. Marquette followed and founded a mission at St. Ignace, which became the largest and most successful mission in the northwest. Here in 1673, just before Marquette started on his famous voyage leading to his discovery of the Mississippi river, were gathered 1300 Ottawas and 500 Hurons. During the following 50 years the Ottawas were *ex patria*, wandering in small groups here and there, some as far south as Detroit and Fort Wayne, others going equally far south on the other side of Michigan and into northeastern Illinois. By 1730 many had returned and once more were living around Big and Little Traverse Bays where they have remained to this day.

The Ottawas say that in this country they had wild potatoes, wild wheat, wild rice, wild turnips, but no wild corn. This last item was something different that grew only in planted fields where they put it. They have no traditions concerning first knowledge of tobacco. Here is an interesting definition for the word Kenekinic which I am repeating just as it was given to me: "Men are sitting around in a circle, not in solemn council, but just enjoying themselves. In the center is a wooden dish filled with tobacco. Kenekinic means—you reach in and help yourself to some tobacco."[1]

The Ottawas claim that their people were not pottery makers. They had this ingenious method for boiling meats without pot: A deer "gut" was cleaned out and filled with water; pieces of meat were put in this, and the "gut" placed by the side of the fire. By the time the "gut" was burned the meat was cooked, or cooked enough.[1]

Mink bones were used for sewing needles. Strange to say, in this birch country, birch bark was not used for canoes by the Ottawas. Dugouts were their chief mode of water transportation, but, when they were traveling on land and came to a body of water that required a boat, they made what they called "temporary canoes" from elm bark. To quote, "When they got to the other side they just left the boat there."[2] This use of large boats fits in with the historic knowledge that the Ottawas were great traders and, perforce, great travelers. They led all the early expeditions down to Montreal to trade with the French, and, after the first contact years, they continued to act as middle-men. The Ottawas claimed the great river as their own to the French, and no others might travel without their consent (2, 2:168). Father Allouez said that, regardless of their nationality, all the early Indian voyagers

[1]Joe Ettawegeshik, Harbor Springs, Michigan.
[2]Fred Ettawegeshik, Harbor Springs, Michigan.

down to Montreal called themselves Ottawas, under whose convoyance the trips were made (2, 2:168).

The Ottawas had a system of patrilineal, exogamous gens. The Ettawegeshiks say their family is called "kewawegwame," the underground or earthen-house people, and they explain this thus: Long ago the Ottawas went into the west to war on enemies. Among the prisoners they brought back a young brave who out there had lived in an earthen house. This foreigner was a great warrior and was permitted to marry into the Ottawa tribe, and for many generations, even to today, his descendants are known as the underground or earthen-house family.

The Ottawas say their language is almost the same as the Chippewa but not mutually intelligible. One must spend a little time in the Chippewa villages, and then the difference disappears. As explained to me, Ottawa is low Chippewa, the former employing a "K" sound where Chippewa uses a "C." The Jesuits in their zeal made a tactical error in baptising the Indians' dying, aged, and infants. This paradox made the new religion a highly questionable venture to strong, vigorous Ottawas in the prime of their pristine faculties, but today they are all devoted Catholics, and most of their children attend parochial schools.

## Bibliography

1. Twaites, Reuben Gold, (ed.), 1896-1901. Jesuit relations and allied documents. Cleveland. 73 vol.

2. Hodge, Frederick Webb, (ed.), 1907, 1910. Handbook of the American Indians north of Mexico. U. S. Bur. Amer. Ethnol. Bull. **30**, 2 vol.

# Culture Parallels to the Delaware Walam Olum

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Recent analysis of the mortuary customs of the Shawnee and other eastern North American tribes served to illustrate the fact that very few traits are likely to be found unique to a single tribe within a given culture area. From a total of several hundred Shawnee burial traits, only 14 traits could be isolated as diagnostic or unique to the Shawnee alone. Moreover, six of these 14 traits occurred in slightly recast form or entirely apart from burial customs in the cultures of eastern North American tribes other than the Shawnee (1).

The uniqueness of the Shawnee burial complex or, I dare say, any other large Shawnee complex lies not in its having an impressive total of traits which are peculiar to this one tribe alone but rather in the fact that the complex as a whole follows a pattern which is distinctive for this tribe.

This fact, that the cultures of various groups within a relatively homogeneous region are apt to show few original traits and are chiefly distinguishable one from the other on the basis of selection and arrangement of elements which have a wider distribution, has received attention from several present-day anthropologists. In a recent noteworthy study Spier (2) has shown that the Ghost Dance, which caused such disturbances among certain Plains tribes at the end of the nineteenth century, was not, as Mooney had held, a new cultural phenomenon developed by the Paviotso to answer spiritual needs of the moment. Rather, the ultimate origin of the Ghost Dance lay in a much older dance form which paralleled the Ghost Dance, for which Spier has coined the name Prophet Dance. This earlier dance form which preceded the Ghost Dance "was known to all the tribes of the northwestern interior, without exception, from the Babine and Sekani on the north to the Paviotso of western Nevada far to the south." In post-white times the Prophet Dance was the source not only of the Ghost Dances of 1870 and 1890 but of several other religious movements among Plateau tribes.

Du Bois (3), working concurrently but independently of Spier on the Feather cult, one of the other religious movements which sprang from the Prophet Dance, also arrived at the conclusion that the Feather cult of the Middle Columbia River tribes was largely derivative of older practices. In her study Du Bois says, "The striking characteristic of the Feather cult was its lack of originality. With the exception of spinning [whirling] and vomiting in the initiation rites, every feature can be traced to some definite and prior source." Ray (4), in a review of Du Bois' study, points out that even the two traits Du Bois mentions are "of doubtful originality" in the Middle Columbia region. "Vomiting is found....as a ritual and curative practice. The whirling is easily associated with the traditional winter dance demonstrations of....persons with whirlwind as a guardian spirit."

What holds for particular complexes also holds true for the culture

of a group as a whole. Webb (5), in searching for distinctive Cherokee traits, found that "it is not easy to determine what traits are definitely diagnostic of Cherokee material culture" since so many traits attributable to the Cherokee have distributions far beyond this particular group. Likewise, in my own study of the comparatively simple culture of the Tübatulabal, a California group, I was able to isolate only three features of Tübatulabal culture which seemed unique to that group alone (6). Since the study was made, one of these three traits has been found among the Kawaiisu (7), southern neighbors of the Tübatulabal, and it seems not only possible, but probable, that the other two features will also eventually be recorded among some of the Great Basin or California groups.

At first glance, the Delaware Walam Olum appears to be a cultural complex unique to a single eastern North American tribe and lacking in antecedents among the Delaware or any other eastern group. As such, we would have valid grounds for questioning its authenticity as a native production. Is its uniqueness, however, due to the fact that no parallels can be found for the various elements or traits which enter into the Walam Olum or rather to the fact that certain elements, common to several Eastern Woodlands groups, occur in unique juxtaposition in the Delaware document?

If we analyze the Walum Olum in respect to its major elements, we find that the production as a whole is the sum of several items, as follows:

1. Pictographs—painted on sticks, used as mnemonic devices, for songs, songs esoteric (?);
2. Primeval water—deluge motives;
3. Genealogy of chiefs—wanderings of bands under chiefs.

Our problem is to see whether any or several of the above traits can be found among eastern North American tribes other than the Delaware. Regarding the first point in the analysis, the use of pictographs, Schoolcraft (8, p. 32) notes in Oneóta that pictographs were used by the Menomini, the Winnebago, the Potawatomi, the Chippewa, and the Ottawa, as well as among the Dakota and Plains tribes to the west and south. Pictographs painted on sticks or tablets of hard wood, in contrast to pictographs painted on birch bark or buffalo skins, have a more restricted distribution; to date we have found specific mention of such only among the Chippewa, Kickapoo, and Delaware. The use of such tablets or sticks for remembering songs, especially songs of a religious or esoteric nature, is found not only among the Delaware but also among the Chippewa and Kickapoo. The manner in which the Chippewa used engraved wooden mnemonic tablets is described in some detail by Kohl (9) and Schoolcraft (8, pp. 27-35); I wish here only to mention certain interesting facts concerning the presence of engraved and painted sticks among the Delaware and Kickapoo.

The use of prayer sticks engraven with mnemonic symbols is first noted for the Delaware *ca.* 1762. At this date a prophet appeared among the Delaware. This prophet, according to Pontiac, the Ottawa chief, had talked with the Great Spirit, received instructions from the divinity concerning the course of life the Delaware should follow, and then had

been given "a prayer, embodying the substance of all that [the Prophet] had heard. . . . [This prayer] was cut in hieroglyphics upon a wooden stick, after the custom of his [the Prophet's] people; and he was directed to send copies of it to all the Indian villages" (10).

Painted sticks graven with "hieroglyphic" or mnemonic characters were also carved by the Kickapoo prophet, Kanakuk, and sold to his followers around 1827-34 (11). None of the Delaware Prophet's prayer sticks seem to have been preserved, but at least one of the Kickapoo prophet's has found its way into the U. S. National Museum, as a gift from Mr. C. H. Bartlett of South Bend, Indiana; Mr. Bartlett obtained the stick from a Methodist missionary of Mill Creek, Indiana (12, pp. 641-1110). This prayer stick tallies with descriptions of Kickapoo prayer sticks given by Catlin (11, pp. 136-137), being made of maple, a little more than 12 inches long, 2 and 9/16 inches wide, and ⅜ of an inch thick. Originally, it was painted a bright red on one side and green on the other. One side is smooth, the other carved with mnemonic figures, many of which "bear some resemblance to the old black-letter type of a missal," and there are traces of Catholic influence in the manner in which the characters are grouped together (12, 698-699). When using the stick, the right index finger was put first under the upper character while repeating the short prayer which it suggested, then under the next, and the next character, and so on to the bottom, the whole prayer being sung as a sort of chant (11, p. 137).

Turning to our second major point, the primeval water-deluge motives which comprise Songs I and II of the Walam Olum, we know that these motives are widespread in eastern North America and also occur in other parts of the continent (13). The version of the deluge myth given in the Walum Olum parallels in structure and in many details versions found among tribes neighboring to the Delaware, such as the Shawnee.

Parallels for our third point are not so easily found among the tribes of eastern North America and will require further research before documented proof that long genealogies of chiefs were preserved in this area. Any references bearing on this point would be extremely valuable; with the aid of mnemonic devices, it does not seem improbable that genealogies of chiefs could have been kept with comparative ease.

At this point in our investigation of culture parallels to the Walam Olum, it does not appear that the document is so aberrant as to be open to suspicion regarding its authenticity as a native production. Rather, distributional evidence seems to show that many of its elements were not limited to the Delaware alone but were fairly widely distributed among Eastern Woodlands tribes. The combination of these elements in the Walum Olum is, so far as we know now, unique to the Delaware. However, this is as we would expect and is consonant with conclusions reached from studies of other cultural complexes to which references were made in the first part of this paper.

## Bibliography

1. Voegelin, Erminie W., 1939. Shawnee mortuary customs; an inquiry into their stability and cultural affiliations. Doctoral dissertation, Yale University Library.

2. Spier, Leslie, 1935. The Prophet Dance of the Northwest and its derivatives; the source of the Ghost Dance. General Series in Anthropol. 1:5-7.

3. Du Bois, Cora, 1938. The Feather cult of the Middle Columbia. General Series in Anthropol. 7:43.

4. Ray, Verne, 1939. Review of Du Bois, The Feather cult of the Middle Columbia. Amer. Anthropol., n.s., 41:320-321.

5. Webb, William S., 1938. An archeological survey of the Norris basin in eastern Tennessee. U. S. Bur. Amer. Ethnol., Bull. 118:371, 374-375.

6. Voegelin, Erminie W., 1938. Tübatulabal ethnography. Anthopol. Rec. 2:1-90. Pp. 6-7.

7. Zigmond, Maurice. Kawaiisu field notes. Ms.

8. Schoolcraft, Henry Rowe, 1845. Oneóta, or characteristics of the red race of America. N. Y. and London.

9. Kohl, J. G., 1860. Kitchi-Gami. Wanderings round Lake Superior. London. Pp. 137-166, 285-297.

10. Parkman, Francis, 1889. The conspiracy of Pontiac and the Indian war after the conquest of Canada. Boston. 1:207.

11. Donaldson, Thomas, 1886. The George Catlin Indian Gallery in the U. S. National Museum (Smithsonian Institution). With memoir and statistics. Ann. Rept. Smith. Instit. 1885 (2, pt. 5).

12. Mooney, James, 1896. The Ghost Dance religion and the Sioux outbreak of 1890. Ann. Rept. Bur. Amer. Ethnol. 14 (2).

13. Thompson, Stith, 1929. Tales of the North American Indians. Cambridge, Massachusetts. P. 279, n. 29; pp. 286-287, n. 57.

# Remarks Regarding the Pictographs of the Walum Olum

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As you know, the *Walum Olum* was the mythological and historic record of the Lenape Indians obtained by Rafinesque in the early eighteen hundreds. It consisted of a series of sticks, painted with red pictographs serving to remind the Lenape of the wording of the songs describing their tribal history.

The outstanding authority on the *Walum Olum*, Dr. Daniel G. Brinton, says on page 161 of his great book, *The Lenape and Their Legends*: "There is generally a distinct, obvious connection between the symbol and the sense of the text sufficient to recall the latter to one who has made himself thoroughly familiar with it." Careful study and observation soon bring out the fact that there are certain symbols which recur as the matter in the text recurs, and it may be of interest to mention a few of the more obvious.

Certain incongruities and differences between the text and the symbols in Brinton's book suggested that a careful comparison should be made between the Rafinesque figures in a photostatic copy of his notebooks and the Brinton pictographs. Fifty-eight mistakes in the Brinton symbols were found, many of them no doubt due to the carelessness of the printer and to the injury of plates during the printing process. This leads to a suggestion that there may be differences between Rafinesque's figures and those of the *Walum Olum* itself, which, sad to state, have disappeared.

There are, of course, certain very obvious meanings where crude drawings are made of the objects mentioned, such as birds, canoes, human figures, the moon, the beaver, spruce and sassafras trees, and the well-known sun symbol.

The human figure is often depicted by the usual vertical oval body with a small circle for the head and straight lines for the legs. In one instance, conversation is indicated by a line drawn between the heads of two figures. Walking or a journey is pictured by the legs being drawn far apart as in the act of walking.

As might be expected, in twenty cases the East is shown as being at the right side of the drawing; North, above the base line or toward the top of the figure in five places; South, below the line in eleven drawings; and West, the left in four instances.

Death or absence is suggested in three figures by the symbol of the object being drawn below the base line.

The various tribes are depicted by several styles of head-dress on the small pictographs of the human figure. For instance, two lines, looking like snake fangs rising from the top of the head, represent the Snake Indians in eleven examples, reptiles in ten cases, and merely evil in fifteen places.

The Lenape Indians are usually pictured by one straight line rising diagonally to the right from the top of the head; sometimes, however,

there are three lines, one vertical and one rising diagonally on each side. Occasionally there is no head-dress at all. A chief generally is shown by the same number of larger and more decorated lines. The Ottawa sign is a short vertical mark and a curved line swinging off to the right from the top of the head; the Talligewi, a straight horizontal line drawn to the right from the middle of the top of the head; and the Talmations—Huron, Iroquois, or Wyandots—a horizontal mark across the top of the head with a vertical line running up from the center of it. Northerners are suggested by a vertical line from the head with a horizontal stroke across the top of it. The symbol of the white man is a circle or a square with a dot in the center with a cross rising from the top.

In five cases, the pictograph for food is a group of small circles or a single small circle, probably representing corn.

Eight times, houses or villages are suggested by parallelograms or a group of parallelograms; in ten instances, such groups of parallelograms seem to tell of favorable circumstances and perhaps indicate many houses.

Land or islands are depicted by several modifications of a semicircle resting on a flat base line.

Nineteen times, the symbol of immortality or divinity is the usual circle with a dot in the center.

Each river has its own symbol, such as the Yellow River, the Fish River, the White River (the Wabash, according to Rafinesque), and the Straight River.

War, fights, battles, enmity, or hatred are shown in twenty-one instances as diagonal crosses.

Bodies of water are pictured by inverted semicircles with a horizontal line showing the level of the water.

Ice is symbolized by the same figure with a double horizontal line.

Extreme cold or snow is shown as an inverted semicircle below which is suspended small tangential lines, possibly representing the aurora or a snowfall.

In four instances, the eastern seashore is indicated by two figures which are easily understood.

Single or double connecting lines seem to show love, relationship, or friendship in ten cases.

An isosceles triangle is the glyph standing for chieftainship in nine instances; in five earlier pictographs, it seems to mean rather the headquarters of the tribe, which is, after all, a related idea.

Doubtless, a thorough study of this subject would reveal many relationships between the pictographs and the subject matter, and the above superficial report should pique our interest and lead to an exhaustive study of this feature of the famous Hoosier Odyssey—the *Walum Olum*.

# The Lenape and Munsee Dialects of Delaware, an Algonquian Language[1]

C. F. VOEGELIN, DePauw University

Over thirty years ago, in an extensive comparative study of Algonquian languages, Michelson found that information on the Delaware language as given by Zeisberger was "not good." The weakness which concerns us is that "The forms of the various dialects are given without assigning each form to its proper dialect.... (1, p. 275)." Michelson supposes that the three Delaware divisions, Munsee, Unami, and Unalactigo, were separate tribes but, nevertheless, spoke mutually intelligible dialects. As a result of some field experience with the Munsee of Kansas and the Delaware of Oklahoma, Michelson revised his conjectures of resemblances between Delaware and other Algonquian languages but did not compare Delaware dialects as such (1, p. 290a).

We have, as the basis for the present study, two sources. The first is an important manuscript of lexical materials, recorded by Dr. Frank Siebert, who says, "My Munsee material was collected from Nicodemus Peters in June, 1938 (aged 77), at Smoothtown, Six Nations' Reserve, Ontario. However, some of that material was collected at the same place in September, 1931, and later revised in 1938. My informant in 1931 was Nicholas Powless (2)." Since both informants mentioned are now dead and since the remaining Munsee speakers of Smoothtown have only a partial command of their native language, it is quite possible that much of this material is now irreplaceable.

The second source is my own field notes of Delaware as spoken by Willie Longbone of Dewey, Oklahoma. The Oklahoma dialect represented is known locally as Lenape.[1]

Neither Dr. Siebert nor I regard our records to be in final phonetic form. Phonetic explanations are made as special problems in orthography arise.[2] The Munsee forms are cited as M., the Lenape forms as L.

1. Initial *wa-* and postvocalic *-wa-* in Munsee appears in Lenape as *o*. M. *wak*, L. *o:k* 'and' (the colon after vowels marks vocalic length); M. *wa:sLew*, L. *ó:sële:w* 'light' (capital L marks a voiceless L); M. *ëwa:n*, L. *aón* 'fog'; M. *pa:wá:law* 'guardian spirit', L. *mpaó:la* 'my guardian spirit'; M. *e:Mhëwá:nës*, L. *e:mhó:nës* 'spoon'. Possibly instances like M. *chihxa:ma:kan*, L. *chi:xamó:kkan* 'comb' imply an underlying **-ëwa:-* for the Munsee *-a:-* which corresponds to the Lenape *-o:-* (doubled consonants, as *-kk-*, are written for a single long phoneme). Instances of Munsee *-wa-* after the consonant *-k-* also appear in Lenape as *-o-*. M. *tëk$^{w}$a:x*, L. *tahkóx* 'turtle'; M. *ëpí:k$^{w}$an*, L. *ahpí:kkon* 'flute';

[1]Field funds for work in Oklahoma were administered by DePauw University; work with informant at Ann Arbor was sponsored by the Linguistic Institute of the University of Michigan.

[2]In place of special phonetic characters, *ë* is used for the schwa symbol (turned *e*), and when no other stress is marked in a given Lenape word, the stress falls on this vowel; *sh* is used for the *s*-wedge symbol (aspirant English 'ship'); *ch* is used for the *c*-wedge (an affricate as in English 'church').

M. *takwáppo* 'he is married', L. *ntakohpu:ha:lkéhena* 'I married her'. In these correspondences, Munsee appears to be the more archaic dialect.

2. However, in preserving *-we:-* and *-wi:-* after *-m-* and *-k-*, Lenape is the more archaic, for in these sequences correspondences show Munsee *-o:-*. L. *kwënaskwé:e:*, M. *kʷëna:skó:tew* 'high weeds'; L. *eha:pchalá:mwi:s*, M. *a:pëchá:li:mo:sh* 'diving duck'; L. *mwe:kkané:yok*, M. *mo:këne:wak* 'dogs' (L. develops *-y-* between *-e:-* and *-o-;* the *-o-* is from *-wa-*, as 1, above).

3. Some Munsee forms with *w* and *wa-* before consonant correspond to Lenape forms without the preceding *w*, *wë-*, which leaves its trace in *-o-* instead of *-a-* after the consonant. Both metathesis of preconsonantic *-w-*, and contraction of *wa-* to *-o-* (see 1, above) are productive features of Lenape phonology. M. *wshayp'e*, L. *shóhpe* shore; *wëla:kan*, L. *ló:kke:ns* 'wooden bowl' (*-n-* before *-s-* or *-sh-* in Lenape nasalizes the preceding vowel); M. *wëla:këna:ho:Nshi*, L. *lo:kkanahú:nshi* 'elm'.

4. A "floating" *-h-* sometimes appears after a vowel in Munsee, but before the corresponding vowel, either in postconsonantic or word-initial position in Lenape. M. *ahpi:s*, L. *hápi:s* 'tumpline'; *M. ohpën*, L. *hópëni:s* 'potato'; M. *wcháppihk* 'medicine', L. *chëphik* 'root'; M. *mohk*, L. *mhúkw* 'blood'; M. *wa:hpán*, L. *hópan* 'lung' (cp. also 1, above). Less regular instances of "floating" *-h-* are M. *ma:kahkw*, L. *mahká:kw* 'leech'; M. *wihsëkhi:m*, L. *wísahki:m* 'grape'.

5. Quite frequently Lenape has a plain stop (less frequently a long stop) where Munsee shows a preaspirated stop. L. *mé:chi*, M. *mehchi* 'now'; L. *tú:pan*, M. *tohpan* 'frost'; L. *ke:tanëttú:wi:t*, M. *keht:nëtto:wi:t* 'god'; L. *nu:wá:ttam* 'I have good sense', M. *nëwewáhtam* 'I know' beside M. *nëwewíhtam* 'I am wise'; L. *tëwé:kw*, M. *tëwehkw* 'lizard' (preaspirated stops never occur in word-final clusters in Lenape; but cp. L. *tëwé:kkok* 'lizards'; L. *wëlakshía*, M. *wëlákshi* 'guts' (the cluster *-hksh-* is not permissible in Lenape; but cp. the relative form, when the cluster is interrupted by the *-ë-* vowel: L. *nu:lahkëshia* 'my guts'). The reverse is also found: Lenape shows preaspiration lacking in Munsee. Incidental examples of this can be found under 1, above. Preaspiration is phonetically clear; impressionistic errors are less probable here than in recording other sound types in Delaware dialects.

6. Munsee retains a word-initial vowel lacking in a few Lenape words. M. *óxkʷew*, L. *xkwe:w* 'women'; M. *a:sëná:mëNshi*, L. *sëna:më:nshi* 'sugar maple'; M. *ëskʷonde*, L. *skóntay* 'doorway' (the use of *-d-*, *-t-* is merely a matter of orthography: in both dialects, the dental stop after *-n-* is voiced). In one instance Lenape retains the initial vowel lacking in Munsee: L. *a:nsí:kkëme:s*, M. *shi:xi:kímëNshi* 'red maple', but this comparison presents other difficulties also.

7. The *-ë-* vowel recorded between consonants in some Lenape words does not appear in the Munsee record. This may reflect a different phonetic interpretation of the phonetic facts. Or it may indicate that Munsee has actually travelled further along the road to developing new clusters. Munsee *-l-* as the second member of such clusters is *L*, while the corresponding *-l-* in Lenape is fully voiced. L. *këla:hí:kkan*, M. *kLa:hí:kën* 'trap'; L. *sú:kkëla:n*, M. *so:kLa:n* 'it is raining'; L. *pëlé:ni:kw*, M. *pLe:n* 'flying squirrel'; L. *we:mahté:kkëni:s*, M.

*we:mëtëkni:s* 'dwarf'. An instance or two is found in which Lenape develops a consonant cluster interrupted in Munsee by a *-ë-* vowel (see example under 2, above).

8. Some Munsee words in *më-*, *m-*, and *n-* appear in Lenape without the initial nasal. M. *mësi:m*, L. *sí:mi:n* 'hickory nut' beside L. *shi:më:nshi* 'hickory nut tree'. Some pairs show also the "floating" *-h-* which appears after a given vowel in Munsee, before the vowel in Lenape (see 4, above): M. *mihLóhsëss*, L. *hilú:sës* 'old man'; M. *míhtëk* 'tree' with *mihtëkwak* 'trees' and L. *híttukw* 'tree', *hítku:k* 'trees'; M. *ptëkkwi:mëNshi* (underlying M. **mtëkkwi:mëNshi*), L. *tëkkwi:më:nshi* 'walnut tree'; M. *n(ë)gwëtën*, L. *kwëttën* 'once'.

9. Lenape appears to tolerate word-final *-kw* in some instances where Munsee reduces *-kw* to *-k*. L. *shëkw*, M. *shëk* 'but'; L. *mi:xá:kkana:kw*, M. *mi:xá:kënak* 'white ash tree' (but with plural suffix, the M. form still lacks postconsonantic *-w*, while the L. form shows the regular change from *-wa-* to *-o-:* L. *mi:xa:kkaná:kok*, M. *mi:xa:kënakal* 'white ash trees'); L. *mhukw*, M. *mohk* 'blood'. But *-kw* is found in word-final in Munsee (see 4, above). The sequence *xwa-* in Munsee appears in Lenape as *xa-* where one would expect to find *xo-* (according to 1, above): M. *xwa:sk$^{w}$i:m*, L. *xáskwi:m* 'corn'.

10. The class of Lenape inanimate nouns in *-ay* is irregular in having beside singular *-ay* an underlying *-e:w-* which yields *-e:(y)o* before the plural suffix *-a* (by regular phonology). The corresponding nouns in Munsee do not undergo either the irregular development of a special singular form in *-ay*, nor the regular phonology of deriving *-o-* from *-wa-*; furthermore the plural suffix in Munsee appears in the full form *-al*. Compare L. *kwshá:tay* with plural *kwsha:té:yo*, and M. *kwsha:tew* with plural *kwsha:te:wal* 'smoke'. See also the example under 6, above.

11. Some animate noun endings appear in reduced form in Lenape, in full form in Munsee. Thus L. *alánkw* with plural *alánkok*, and M. *ëla:nk$^{w}$ew* with plural *ëla:nk$^{w}$ewak* 'star'.

12. The glottalized stop is a specialized development in the Munsee dialect. Michelson reported that every stop might be glottalized, but did not assign this development to any specific dialect (1, p. 290a). Our examples show two cases of glottalized *p* in Munsee which correspond to *p* in Lenape. M. *wshayp'e*, L. *shóhpe* 'shore'; M. *shwëpp'i*, L. *shuwánpi* 'salt water'.

13. In general, vowels of the two dialects are the same. An occasional vowel of one dialect may be reduced to a *-ë-* vowel in the other (see 11, above), possibly as a result of fast speech. In the following example, Lenape *-ë-* is probably phonemically *-ë-*; it is, at least, subject to the regular syncope of *-ë-* in syllabic-final before suffix: L. *pu:pú:kkwësh* with plural *pu:pú:kwshak*, and *popokwi:s* 'oriole'.

14. Lenape *-u-*, *-u:-* is recorded where Munsee shows *-o-*, *-o:-*. This fact is perhaps not unrelated to the derivation of some Lenape *-o-*, *-o:-* from *-wa*, *-wa:-*, a development which is not shared by Munsee. If such derivation, with analogical extension, will account for the origin of Lenape, *-o-*, *-o:-*, then Lenape *-u-*, *-u:-* can really be said to be identical with Munsee *-o-*, *-o:-*. The difference between Lenape *-u-* and Munsee *-o-*

is orthographic, not phonemic. Phonemically then, Munsee has only one high back vowel, *-o-*, while Lenape has the same vowel which in our orthography is written *-u-*, and in addition Lenape has a second high back vowel, *-o-*, not to be confused with Munsee *-o-*. L. *yúkwe*, M. *yo:kwe* 'now'; L. *kwënënuxkw*, M. *kʷënëmoxkʷ* 'otter'; L. *mënú:tte:s*, M. *mënó:te:s* 'pouch'; L. *ká:kku:n*, M. *ka:kon* 'leggings'; L. *mëkú:s*, M. *mëko:s* 'awl'; L. *wiyú:s*, M. *wëyó:s* 'meat'; L. *mu:s*, M. *mo:s* 'elk'; L. *hu:s*, M. *hohs* 'kettle'; L. *ku:n*, M. *ko:n* 'snow'; *L. ki:shu:x*, M. *ki:shox* 'sun'.

15. Many words in the two dialects are identical, if we discount orthography and count only the phonemic facts (see 14). Additional examples may be cited at random: *wte:* 'heart'; *ke:kw* 'wampum'; *wi:nínkwës* 'mink'; *énta* 'there'; *é:li* 'because'.

16. Words which are otherwise identical in the two dialects may differ in inflectional endings. Thus, the inanimate plural suffix appears as *-al* in Munsee, but without the *-l*, as *-a*, in Lenape. Both dialects give *mi:n* 'huckleberry', but M. *mi:nal*, L. *mí:na* 'huckleberries'. Both dialects give *wí:na:kw* 'sassafras tree', but the gender of this word, as marked by plural suffixes, appears to be animate in Lenape, inanimate in Munsee: L. *wi:na:kok*, M. *wi:na:kwal* 'sassafras trees'. Both dialects give *ménkwew* 'Seneca', and the animate plural suffix for both dialects is *-ak*, but in suffixation the sequence of phonemes is preserved only in Munsee; in Lenape it is phonologically contracted (see 1, above): M. *menkwé:wak*, L. *menkwé:yok* 'Senecas'. Beside the participle suffix *-t*, there is an agentive suffix *-s*. This may be reflected in the correspondence of nouns in *-s* and in *-t*. L. *hémpës*, M. *he:mbët* 'shirt'.

17. Some instances of partial similarities may be classified. Compound words may have one stem identical in the two dialects, the other not. M. *ëmangëme:kw*, L. *xínkome:kw* '[one] big fish'; cp. L. *amankamé:kkok* '[many] big fish'. A stem which appears freely in initial position in one dialect may be restricted to non-initial position in the other dialect. M. *toLpew* 'turtle', L. *pi:sëlatú:lpew* 'soft shell turtle'. Both dialects give *lënu* 'man', and in the non-initial by-form both dialects show syncope of the *-ë-* vowel, but in Munsee a consonant cluster results while in Lenape the neighboring consonants contract to a single long phoneme. M. *lëpëwe:wí:lno*, L. *lëpwe:ínnu* 'sage, wise man'; M. *ma:nëtwí:lno*, L. *manëttu:wínnu* 'shaman, spirit man'. Specialized meaning may result in one dialect, not in the other. M. *mohkëtonës* 'salamander', L. *mhukwtú:ne:* 'he has a bloody mouth'. Both dialects give *manëttu* 'spirit'; Lenape, but not Munsee, has developed a non-initial by-form. L. *mahtánTu*, M. *me:tsi:t manëtto* 'no good spirit, devil'. Analysis of partial similarity is far from easy: L. *xe:s*, M. *xay* 'hide'; L. *aé:sës*, M. *ëwe:yëyës* 'animal'; L. *kwi:ppëlënay*, M. *ëkʷi:pLa:wën* 'hoe'; L. *maná:tay*, M. *mëna:hën* 'island'; L. *panshpe:kw*, M. *shpáNshpex* 'muskmelon'; L. *chi:skúkku:s*, M. *ki:shko:sh* 'robin'.

18. Instances of complete lexical dissimilarity between the dialects are relatively infrequent.

## Literature Cited

1. Michelson, Truman, 1906-07. Preliminary report on the linguistic classification of Algonquian tribes. Bur. Amer. Ethnol. Rept. 28:221-290b.

2. Personal communication. I am grateful for permission to use this material.

# Birch Bark Records Among the Chippewa

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Picture writing was a trait with a wide distribution among the North American Indians. Among the Algonquian speaking tribes there were few, if any, breaks in the distribution of the practice. The techniques used were principally line drawings in ashes or sand, charcoal on blazed surfaces of trees, paints on leather, and incisions on pieces of bark, wood, or rock.

Examples of picture writing that may be definitely attributed to the Chippewa are fairly common, principally because of their residence in the growing range of the birch tree. The bark of this tree served them for many purposes—to cover their dwellings, to make containers and utensils of various sorts, to build canoes, and to carry records. The drawings in sand or ashes and on trees were not very permanent, and the drawings or paintings on rock, while permanent, were not portable and hence did not remain in the possession of the maker or his heirs. Birch bark, however, was not only obtained but worked and preserved with ease. Wooden tablets possessed the same attributes of permanence and portability, but they are not as numerous as the birch bark rolls, probably because they required more exertion and skill in manufacture. The only differences between the wooden tablets and the birch bark rolls, aside from the material, are the greater use of color and the generally better workmanship in the tablets. The one difference is explained by the fact that birch bark does not take color readily. On the other point it must be added that some of the figures on birch bark were equal or superior in artistry to those on the wooden tablets.

The purpose of an individual record determined the type of symbols used, the size of the record, and perhaps also the excellence of the delineation. The drawings were of two general types on the basis of the subject matter: first, those in which the subject matter was understood only by instructed persons, and, second, those intended to be understood by the general public. The second type included totem marks, names of persons, messages left by travellers, records of time, *et cetera*. The first type consisted principally of the records and songs of the Midewiwin, other songs, records of dreams and drawings used as charms.

The figures used in the records of the public type were mainly descriptive in character and possibly also related to the sign language of the Indians as maintained by Rafinesque (1). The figures used in the records of the Midewiwin were ideographic, esoteric, and mnemonic although they may have had their origin in the sign language, that is, they suggested an idea to a person who had had the proper instruction and served to recall definite words which were not indicated in the drawing. Not only was instruction as to the meaning of each figure required but also information on which was the initial figure and the direction of reading in each record. The Chippewa never

standardized the direction of their writing, and, consequently, one roll will read from left to right, another from right to left; others progressed clockwise or counter-clockwise around the edge of a piece of bark, and some of several rows of figures had alternate rows read in opposite directions.

The bark pieces varied in size from a few square inches for a charm drawing to a roll three or four feet in width and fifteen feet or so in length for a chart showing the origin or the degrees of the Midewiwin.

The excellence of the drawing on different bark records varied with the purpose and the skill of the artist. Some were very crude and some were very carefully executed. A birch bark conveying a message of only temporary importance would not have the care lavished on it that might be bestowed upon the record of a band's migration or its success in war which might be cherished for several generations. The same difference in execution is found in the birch bark records relating to the Midewiwin as in the records of the public type. Ordinarily, the records of songs were made by each individual to remind him of the exact words and order of the songs as he learned them. These were his personal possessions and were either buried with him or burned after his decease. The pictographs were often hastily sketched as pictographic excellence was subordinate to a grasp of the meaning of the song and its exact words. On the other hand, the birch bark rolls showing the origin of the Midewiwin, the charts of the different degrees, and the movements in each ceremony were used in instruction, shown to the assembled initiates, and were expected to be handed down from generation to generation. Naturally, these usually show much more care in their manufacture than the song records of individuals.

The first birch bark writings mentioned by the early explorers were messages left by travellers on their abandonment of campsites. Other messages and maps received occasional notice during the next century or so, but it was not until about the beginning of the nineteenth century that the Midewiwin charts and other song records were given much attention. Cass and Schoolcraft called the song records "music boards." They both collected numerous examples, and the latter reproduced many of them (**5**, **2**, **5**, and **6**). Kohl collected many "bark books," as he called them, in his travels around Lake Superior. Some of these he reproduced in his published account with the explanations he received for them from the Indians (**4**, pp. 157, 287, 292). He kept looking for musical notes on the birch barks, but in vain (**4**, p. 286). As Hoffman, who obtained or copied many rolls relating to the Midewiwin, said, the musical rendering of a song by one person might be so different from that of the person from whom he learned it as to be unrecognizable without the words (**3**).

In more recent years Miss Frances Densmore obtained accompanying drawings for the songs she collected among the Chippewa of northern Minnesota. These drawings, she found, were recognized in distant localities and elicited the same songs. Also, on playing over a song obtained in one community to a member of a distant one, she was shown the proper drawing to accompany it (**2**).

My efforts to find bark records among the inhabitants of a Chippewa village in northern Michigan this past summer were fruitless. One man was pointed out as the owner of some but he denied having any. In the meetings of the Midewiwin, which are still held several times a year, sand drawings are used to instruct the candidates instead of bark charts. There is a vestige of inscribed wooden tablets to be found in the little paddle-shaped wooden sticks marking each grave in their cemetery. On these sticks the only figure is the totem of the deceased placed upside down to denote death.

## Literature Cited

1. Brinton, Daniel G., 1885. The Lanâpé and their legends. Philadelphia. P. 152.
2. Densmore, Frances, 1910. Chippewa music. Bur. Amer. Ethnol. Bull. 45:16.
3. Hoffman, W. J., 1891. The Midewiwin or "Grand Medicine Society" of the Ojibwa. Ann. Rept. Bur. Amer. Ethnol. 7:273.
4. Kohl, Johann G., 1860. Kitchi-Gami. London.
5. Schoolcraft, Henry R., 1851-60. Information respecting the history, conditior and prospects of the Indian tribes of the United States. Philadelphia. 6 vol.

# BACTERIOLOGY

Chairman: W. A. JAMIESON, Eli Lilly and Company

The section on bacteriology introduced two new features this year, a panel discussion on a subject of vital interest and a paper reviewing in detail a problem of current importance.

The panel discussion on the teaching of bacteriology was directed by S. E. Hartsell, Purdue University. The following aspects of the subject were presented:

Teaching Bacteriology to Medical Men.—T. B. Rice, Marcus W. Lyon, Jr.

Teaching Bacteriology in an Arts College.—M. S. Markle, A. R. Bechtel.

Teacher Training in Bacteriology.—C. M. Palmer, P. A. Tetrault.

Training Bacteriologists for Health Departments.—C. G. Culbertson, C. K. Calvert.

Training Bacteriologists for Research and Industry.—W. A. Jamieson, Paul Prickett.

Among those participating in the general discussion of this subject were: N. Paul Hudson, Ohio State University; W. LeRoy Mallmann, Michigan State College; Fred W. Tanner, University of Illinois.

Dr. Brueckner's paper on Equine Encephalomyelitis makes available in one article the essential pertinent information and a good bibliography on this timely subject.

Dr. Donna G. Graam was elected chairman of the section for 1940.

## ABSTRACT

**Possibilities in biological research.** W. A. JAMIESON, Eli Lilly and Company.—One often is confronted with the thought that so much has been accomplished in the development of biological therapy that little remains to be done. A review of the advancements in diphtheria immunization, the treatment of pneumonia, the development of germicides, and the improvement in bacterial antigens shows definitely that some of the greatest steps forward have been made after many had considered the problems finished. In addition to the improvement of methods already available, there are the fields of tuberculosis, cancer, *Streptococcus viridans* infections, and rheumatism. Because of our increased knowledge and improved technique, there are even greater possibilities in biological research today than there were a quarter century ago.

# Correlation of the Oil-Water Distribution Ratios of Some Substituted Acids with Their Bacteriostatic Properties[1]

GEORGE C. GROSS with ED. F. DEGERING and P. A. TETRAULT, Purdue University

As Degering and Goshorn (1) have shown that the bacterial effect of phenylalkanoic acids increases with increasing oil solubility, this work was undertaken to see if such a correlation holds for other acids and for solutions other than aqueous.

## Experimental

Twenty-five milliliters of the 0.005 M acid solution was placed in an oil sample bottle and 25 ml. of U.S.P. cottonseed oil added. This mixture was shaken at room temperature for 18 hours. The oil and water emulsion was separated by centrifuging at approximately 2000 r.p.m. Ten milliliters of the aqueous layer was titrated with 0.0096

TABLE I.—The Distribution Ratios of Phenylalkanoic Acids in 5% Ethylene Glycol,* in 10% Ethanol,* and in Water, and Their Bactericidal Properties in Water

| Acid | Ratio | | | Bactericidal Tests† (1) | |
|---|---|---|---|---|---|
| | 5% Glycol | 10% Ethanol | Water (1) | Colon. | Aureus |
| Alpha Series— | | | | | |
| Benzoic | 5.1 | 5.0 | ..... | 1/900 | 1/100 |
| Phenylacetic | 2.0 | 1.8 | 1.8 | 1/800 | 1/700 |
| Phenylpropionic | 6.2 | 5.8 | 5.6 | 1/950 | 1/650 |
| Phenylbutyric | 20.9 | 12.6 | 14.4 | 1/1600 | 1/1600 |
| Phenylvaleric | 74.0 | 32.1 | 26.4 | 1/2000 | 1/2300 |
| Omega Series— | | | | | |
| Phenylpropionic | 9.1 | 6.8 | 6.6 | 1/1000 | 1/1200 |
| Phenylbutyric | 25.2 | 19.3 | 14.8 | 1/1300 | 1/1400 |
| Phenylvaleric | 42.7 | 52.0 | 28.8 | 1/2500 | 1/2500 |

*Highest bacteriostatically inactive concentrations (1).
†Maximum effective dilution is expressed in gm./ml.

[1]This is the sixth of a series of articles on the effect of pH and substituent groups on the bacteriostatic and bactericidal properties of certain antiseptics. The other articles are: 1. Antiseptic and bactericidal action of benzoic acid and inorganic salts. Ind. and Eng. Chem. 30:646; 2. Preparation of alpha-phenylalkanoic acids and a study of their bactericidal and physical properties. Journ. Amer. Phar. Assoc. 27:865-870; 3. Bactericidal properties of commercial antiseptics. Ind. and Eng. Chem. 31:742; 4. The effect of para-substituents on the bacteriostatic properties of phenylacetic acid. Journ. Amer. Phar. Assoc. 28:514-519; 5. A further study of the effect of pH on the bactericidal properties of some commercial antiseptics. Ind. and Eng. Chem. Vol. 43 (1940).

sodium hydroxide, using phenolphthalein as the indicator. Nitrogen was bubbled into the solution to prevent carbon dioxide absorption. Two samples of each acid were shaken, and two titrations were made on each sample. The results checked to 0.10 ml. of base. From the known normality of the original solution and the calculated normality of the extracted solution the ratio can easily be calculated. A blank was run and the normality of the acid solution produced by the solvent in contact with the oil subtracted from the titrated normality.

TABLE II.—Substituted Mandelic Acids—Aqueous Solutions*

| Acid | Ratio | Bact. Tests† (2) |
|---|---|---|
| Mandelic | 0.51 | 1 |
| *p*-methylmandelic | 0.28 | 1-2 |
| *p*-ethylmandelic | 0.67 | 1-4 |
| *p*-n-propylmandelic | 2.12 | 1 or less |
| *p*-iso-propylmandelic | 1.78 | 1 |
| *p*-n-butylmandelic | 5.66 | 1 or less |
| *p*-sec-butylmandelic | 3.85 | 1-2 |
| *p*-ter-butylmandelic | 3.19 | less than 1 |
| *p*-ter-amylmandelic | 7.76 | 1 or less |
| 2,4,6-trimethylmandelic | 0.78 | 1.4 |
| *p*-chloromandelic | 0.56 | 2.4 |

*Prepared by J. L. Riebsomer of DePauw University.
†Based on mandelic acid as 1.

TABLE III.—Para-Substituted Phenylacetic Acids—Aqueous Solutions*

| Acids | Ratio | Bacteriostatic Tests† | |
|---|---|---|---|
| | | Staph. Aureus | Esch. Coli. |
| Hydroxyphenylacetic | 0.09 | Less than 1/1000 | |
| Aminophenylacetic | 0.13 | 1/1500 | 1/2000 |
| N-Chloroacetylaminophenylacetic | 0.25 | 1/3000 | 1/3000 |
| N-Acetylaminophenylacetic | 0.28 | Less than 1/1000 | |
| Phenylacetic | 1.85 | 1/1000 | 1/1500 |
| Nitrophenylacetic | 2.71 | 1/2000 | 1/610 |
| Methoxyphenylacetic | 2.79 | 1/1000 | 1/1500 |
| Ethoxyphenylacetic | 8.28 | 1/1000 | Less than 1/1000 |
| Ethylphenylacetic | 36.1 | 1/2500 | 1/1000 |
| Chlorophenylacetic | 23.7 | 1/3000 | 1/1000 |
| Iodophenylacetic | 42.9 | 1/4000 | Less than 1/1000 |
| Bromophenylacetic | 73.1 | 1/5000 | Less than 1/1000 |

*Acids prepared by W. A. Bittenbender.
†Tests indicate the highest dilution negative growth and were made by Professor P. A. Tetrault.

## Conclusions

From Table I it is readily seen that, with one exception which is well within the accuracy of the tests, the relative oil-solvent distribution ratio parallels the bactericidal action. Benzoic acid seems to be out of place but follows the general rule that the first member of an homologous series shows unusual properties.

In Table II there is practically no correlation between the distribution ratios and the bacteriological tests except in the first three members. Even here mandelic acid shows a higher distribution ratio but lower bacterial action. This table and Table III bring out the point that the ratios of alkyl-, alkoxy-, and similar substituted compounds cannot be compared with compounds substituted with halogens, or with nitro-, hydroxy-, and other polar groups.

Table III presents fairly consistent data. The ratios show that the *p*-hydroxy-derivative will be the weakest, and this is borne out by the tests. It also shows *p*-nitrophenylacetic acid to be better than phenylacetic acid. Most striking of all the predictions is the curious behavior of the halogen-substituted compounds. The bromo-phenylacetic acid is shown to be better than either the chloro- or the iodophenylacetic acid. The results with *Esch. coli* are quite varied.

In general it can be seen that the oil-water distribution ratio is helpful in predicting the relative bacteriostatic action of certain types of closely related compounds, thus serving as a confirmatory check on standard bacteriostatic or bactericidal tests, but the principle does not appear to be applicable to all types of bacteriostatic agents. The correlation seems to apply, in general, to members of the same homologous series or to members of the same solubility group.

## Bibliography

1. Goshorn, R. H., and Ed. F. Degering, 1938. Preparation of alpha-phenylalkanoic acids and a study of their bactericidal and physical properties. Journ. Amer. Pharm. Assoc. **27**:865.

2. Riebsomer, J. L., et al, 1938. The preparation of substituted mandelic acids and their bacteriological effects. Journ. Amer. Chem. Soc. **60**:1015, 2974.

3. Tetrault, P. A. Private communication.

# Sulfo-Merthiolate as a Germicide

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## Introduction

Twelve years ago we tested solutions of 'Sulfo-Merthiolate' (Sodium p-Ethyl Mercuri Thiophenylsulfonate, Lilly) for antibacterial action and toxicity. When tested by the Reddish method, it was found to be germicidal in dilutions of 1-1,000 and 1-2,000 but not 1-4,000 for *B. typhosus* and *Staphylococcus aureus*. It was tolerated in doses up to and including 20 mg. per kilogram intravenously by rabbits and in doses up to and including 40 mg. per kilogram intravenously by mice. Preparation of the drug at that time included difficulties of such order that a more complete laboratory study was not then attempted. In general, the drug is quite similar chemically to 'Merthiolate' (Sodium Ethyl Mercuri Thiosalicylate, Lilly) (1 to 11) and possesses the distinct advantage of being soluble over a wide acid, neutral, and alkaline pH range.

During the past two years more adequate amounts of 'Sulfo-Mer-

Table I.—Germicidal Test of 'Sulfo-Merthiolate'
Test culture: *B. typhosus*, Hopkins strain, in 0.5 cc. doses. "Medication" at 20°C

| Germicide Dilutions (5 cc.) | Readings of culture growth in incubated broth tubes planted with test culture medicated for: | | | | | |
|---|---|---|---|---|---|---|
| | 5 minutes | | 10 minutes | | 15 minutes | |
| | Direct culture | Sub-culture | Direct culture | Sub-culture | Direct culture | Sub-culture |
| Phenol 1-80 | − | | − | | − | |
| 1-90 | + | | + | | − | |
| 'Sulfo-Merthiolate' 1-1000 | − | − | − | − | − | − |
| 1-2000 | − | − | − | − | − | − |
| 1-3000 | − | − | − | − | − | − |
| 1-4000 | − | + | − | + | − | − |

thiolate' have been prepared and a wider laboratory study of the drug made. This report presents the results of these tests.

## Experiments

**Germicidal tests.** 'Sulfo-Merthiolate' was subjected to standard germicidal tests against the Hopkins strain of *B. typhosus* and *Staphylococcus aureus* strain No. 209 at 20°C. Plantings were made in the usual way to tubes of the specified beef extract broth. After two days incubation at 37°C., all negative mercurial tubes were subcultured and reincubated, and both direct and subculture tubes were given final readings seven days after the test was done. The results of these tests are shown in Tables I and II.

These test-tube experiments show that 'Sulfo-Merthiolate' has a strong antibacterial action against the strains of bacteria commonly used in preliminary experiments on various germicides. Inasmuch as "phenol coefficients" of germicides tested in media nearly entirely aqueous in character can have very little importance, we shall not attempt to assay such figures.

The above tests in which 'Sulfo-Merthiolate' dilutions were made in water were repeated with 'Sulfo-Merthiolate' (but not phenol) dilutions made in sterile normal horse serum. One per cent 'Sulfo-Merthiolate'

TABLE II.—Germicidal Test of 'Sulfo-Merthiolate'
Test culture: *Staph. aureus* No. 209 in 0.5 cc. doses. "Medication" at 20°C

| Germicide Dilutions (5 cc.) | Readings of culture growth in incubated broth tubes planted with test culture medicated for: | | | | | |
|---|---|---|---|---|---|---|
| | 5 minutes | | 10 minutes | | 15 minutes | |
| | Direct culture | Sub-culture | Direct culture | Sub-culture | Direct culture | Sub-culture |
| Phenol 1-60..... | + | | | | | |
| 1-70..... | + | | + | | + | |
| 'Sulfo-Merthiolate' 1-1000..... | − | − | − | − | − | − |
| 1-2000..... | − | − | − | − | − | − |
| 1-3000..... | − | + | − | + | − | + |
| 1-4000..... | − | + | − | + | − | + |

TABLE III.—Germicidal Test of 'Sulfo-Merthiolate' in Normal Horse Serum Test culture: *B. typhosus*, Hopkins strain, 0.5 cc. doses. "Medication" at 20°C

| Germicide Dilutions (5 cc.) | Readings of culture growth in incubated broth tubes planted with test culture medicated for: | | | | | |
|---|---|---|---|---|---|---|
| | 5 minutes | | 10 minutes | | 15 minutes | |
| | Direct culture | Sub-culture | Direct culture | Sub-culture | Direct culture | Sub-culture |
| Phenol 1-80 | − | | − | | − | |
| 1-90 | + | | − | | − | |
| 'Sulfo-Merthiolate' 1-1000 | − | − | − | − | − | − |
| 1-2000 | − | − | − | − | − | − |
| 1-3000 | − | − | − | − | − | − |
| 1-4000 | − | + | − | + | − | + |

solution was diluted with whole normal horse serum to prepare the necessary series of germicide dilutions. By this technique the 1-1,000 'Sulfo-Merthiolate' dilution contained 90 per cent horse serum, the 1-2,000 dilution contained 95 per cent horse serum, et cetera; all mercurial dilutions therefore contained 90 per cent or more of whole normal horse serum. The results of these germicidal tests are shown in Tables III and IV. The results indicate that the antibacterial action of 'Sulfo-Merthiolate' persists well in strong serum concentrations. It was further observed that 'Sulfo-Merthiolate' was quite free of serum-precipitating properties.

**Bacterial inhibition tests.** 'Sulfo-Merthiolate' was diluted in sterile beef extract broth, and 5 cc. amounts of various dilutions were planted with a loop of twenty-four hour broth culture respectively of *B. typhosus*, Hopkins strain, and *S. aureus* No. 209. Both series of tubes were incubated at 37°C. for a week, and readings of growth noted as shown in Tables V and VI. The results indicate that 'Sulfo-Merthiolate' in dilutions of over one in one million to one in four million is inhibitory for ordinary bacteria. These values are somewhat higher than those originally reported of 'Merthiolate' (1) and equal those subsequently reported (10); however, at the time the present tests were conducted, 'Merthiolate' was found to be closely similar to 'Sulfo-Merthiolate' in

inhibition qualities as indicated by the results in footnotes at the bottom of Tables V and VI.

**Fungicidal tests.** 'Sulfo-Merthiolate' in aqueous solution has been tested against fungi associated with ringworm, using the technique heretofore reported (9). We have noted strong fungicidal action as indicated in Table VII. The 1-10,000 dilution of 'Sulfo-Merthiolate' (but not the 1-20,000 dilution) proved fungicidal for *Trichophyton purpureum* No. 4183, with final reading of all culture tubes being made after seven days incubation. Furthermore, poured plates of this organism showed "clearings" 7.5 cm. in width when streaked with a loop of 'Sulfo-Merthiolate' 1-1,000 and incubated seven days. These test results are quite similar to those reported for 'Merthiolate' (9) and compare favorably with results heretofore obtained with other drugs of this class.

**Hemolytic, precipitation, and irritation tests.** 'Sulfo-Merthiolate' in concentrations up to and including 1-200 (the strongest tested) in whole horse serum has caused no precipitation when heated at 37°C. for twenty-four hours. It is hemolytic for washed sheep cells (unit equivalent to erythrocytes contained in one-fortieth cc. of whole blood) in a concentration of 1-250 but not 1-500. These values are closely comparable to results obtained with 'Merthiolate' (1 to 11) and indicate considerable tolerance by body fluids and cells.

TABLE IV.—Germicidal Test of 'Sulfo-Merthiolate' in Normal Horse Serum Test culture: *Staph. aureus* No. 209 in 0.5 cc. doses. "Medication" at 20°C

| Germicide Dilutions (5 cc.) | Readings of culture growth in incubated broth tubes planted with test culture medicated for: | | | | | |
|---|---|---|---|---|---|---|
| | 5 minutes | | 10 minutes | | 15 minutes | |
| | Direct culture | Sub-culture | Direct culture | Sub-culture | Direct culture | Sub-culture |
| Phenol 1-60 | − | | − | | − | |
| 1-70 | + | | + | | + | |
| 'Sulfo-Merthiolate' 1-1000 | − | − | − | − | − | − |
| 1-2000 | − | − | − | − | − | − |
| 1-3000 | − | + | − | − | − | − |
| 1-4000 | − | + | − | + | − | − |

TABLE V.—Bacterial Inhibition Tests of 'Sulfo-Merthiolate'
Test culture: *B. Typhosus*, Hopkins strain.

| Germicide Dilutions in Broth (5 cc.) | Readings of culture growth in broth tubes containing varying dilutions of germicide and planted with 1 loop 24-hour broth culture and incubated for: | | | | |
|---|---|---|---|---|---|
| | 24 hours | 96 hours | 120 hours | 144 hours | 168 hours |
| 'Sulfo-Merthiolate' 1-600,000 | − | − | − | − | − |
| 1-800,000 | − | − | − | − | − |
| 1-1,000,000 | − | − | − | − | − |
| 1-1,200,000 | − | − | − | − | − |
| 1-1,400,000 | − | − | − | + | + |
| 1-1,600,000 | − | + | + | + | + |

Note: On same day of this test 'Merthiolate' 1-1,200,000 proved inhibitory or same culture at 168 hours incubation.

We have subjected 'Sulfo-Merthiolate' to human skin tests on individuals quite susceptible to several irritating substances, including common adhesive plaster. In these tests different concentrations of 'Sulfo-Merthiolate' were applied to thoroughly cleansed skin of the upper arm by means of wet cotton pledgets held in place under rubber dam for eighteen hours. Dilutions of bactericidal activity (1-1000 to 1-4,000) showed no reaction whatever, either when aged up to a year or when heated at 60°C. for a month. To get a final end point of beginning irritation comprising slight redness, it was necessary to use a concentration of 1-25. Under the same condition 'Merthiolate' has given a slight reaction at a concentration of 1-100.

When tested under the same conditions, we have found 'Sulfo-Merthiolate' non-irritating to human skin when incorporated as a 1-1,000 concentration either in a dusting powder base, tragacanth jelly base, or tincture, or as a 1-2,000 concentration in an ointment base.

**Toxicity tests.** Six mice injected intravenously with an early preparation of 'Sulfo-Merthiolate' indicated the drug was tolerated in doses up to and including 40 mg. per kilogram. Twenty rabbits injected intravenously with four different preparations indicated that doses of 20 mg. per kilogram, but not 30 mg., were tolerated. We have recently treated forty-eight rats intravenously with 'Sulfo-Merthiolate' in doses of 20 mg. per kilogram up to 75 mg. per kilogram with increments of 5 mg.

doses, each of the twelve doses therefore being administered to four rats. At the end of seven days one rat out of four had died on the 30, 45, 55, 60, 65, and 70 mg. doses, and two rats out of four had died on the 75 mg. dose. We then treated sixteen rats intravenously with doses of 40, 60, 80, and 100 mg. per kilogram, using four rats on each dose. Within seven days none of the rats on 40 or 60 mg. doses had died. Two rats, quite ill on the 80 mg. doses, were sacrificed on the fifth day for study; the other two died by the seventh day. All four rats on the 100 mg. dose died by the seventh day, and one of these was found sufficiently early for microscopic study. Both of the rats treated intravenously with 80 mg. 'Sulfo-Merthiolate' per kilogram and sacrificed on the fifth day presented empty urinary bladders on autopsy and possibly were anuric. Only the kidneys showed noteworthy lesions. The first animal had many convoluted tubules with parenchymatous degeneration and a few with necrosis. Many tubules also showed evidence of regeneration and were lined by cells which had flattened, had basophilic cytoplasm, and showed numerous mitoses. The second animal's kidneys resembled those of the first. Many convoluted tubules were lined by regenerated cells and mitoses were frequently seen.

TABLE VI.—Bacterial Inhibition Tests of 'Sulfo-Merthiolate'
Test culture: *Staphylococcus aureus* No. 209.

| Germicide Dilutions in Broth (5 cc.) | Readings of culture growth in broth tubes containing varying dilutions of germicide and planted with 1 loop 24-hour broth culture and incubated for: | | | | |
|---|---|---|---|---|---|
| | 24 hours | 96 hours | 120 hours | 144 hours | 168 hours |
| 'Sulfo-Merthiolate' 1-1,000,000..... | − | − | − | − | − |
| 1-2,000,000..... | − | − | − | − | − |
| 1-3,000,000..... | − | − | − | − | − |
| 1-4,000,000..... | − | − | − | − | − |
| 1-5,000,000..... | − | + | + | + | + |
| 1-6,000,000..... | − | + | + | + | + |
| 1-7,000,000..... | + | + | + | + | + |

Note: On same day of this test 'Merthiolate' 1-5,000,000 proved inhibitory for same culture at 168 hours incubation.

TABLE VII.—Fungicidal Test of 'Sulfo-Merthiolate'
Test culture: *Trichophyton purpureum* No. 4183 of the American Type Culture Collection in doses of 0.5 cc. of a 10 cc. water suspension of 7-day slant culture. "Medication" at 20°C

| Germicide dilutions (5 cc.) | Readings of culture growth, after 7 days incubation, in agar tubes planted with test culture medicated for: | | |
|---|---|---|---|
| | 5 minutes | 10 minutes | 15 minutes |
| 'Sulfo-Merthiolate' 1-1000 | − | − | − |
| 1-5000 | − | − | − |
| 1-10,000 | − | − | − |
| 1-20,000 | + | − | − |
| 1-40,000 | + | + | + |
| 1-60,000 | + | + | + |

The rat treated intravenously with 100 mg. 'Sulfo-Merthiolate' per kilogram and found dead on the sixth day was possibly anuric, the bladder being empty. Microscopically the kidneys were seen to be severely injured. The epithelium of many of the glomerular capsules and convoluted tubules showed severe parenchymatous degeneration. Some convoluted tubules showed fatty degeneration, and in many the cells were necrotic. In a few foci, there was evidence of slight regeneration.

Aside from the animals enumerated above, thirty guinea pigs have been injected hypodermically with 1 cc. of diphtheria toxoid preserved with 'Sulfo-Merthiolate' 1-10,000. No local lesions were observed. These guinea pigs will be referred to further.

**'Sulfo-Merthiolate' as a biological preservative.** Close similarity of 'Sulfo-Merthiolate' to 'Merthiolate' as noted thus far indicated the former might be used as a biological preservative as has 'Merthiolate' (11). A comparative test was, therefore, conducted, using a single lot of diphtheria toxoid subsequently divided into two portions. To one of these, 'Sulfo-Merthiolate' 1-10,000 was added, and, to the other, 'Merthiolate' 1-10,000 was added. Both antigens were then heated at 37°C. for four months. Immunization of guinea pigs was done with samples of toxoid removed after two months heating and after four months heating. In these tests a total of sixty guinea pigs of 300 grams weight were given single 1 cc. doses of the respective toxoids. For testing the degree of anti-diphtheria immunity which these toxoids incited, 10, 20, and 40

MLD of diphtheria toxin were administered to different subgroups of forty-five of these guinea pigs one month after they had received the single immunizing dose of toxoid. Fifteen guinea pigs had died of intercurrent pneumonias. Table VIII shows the results of these immunity tests. Totals of all survivals and deaths following the toxin doses used show that 48 per cent of the guinea pigs immunized with 'Sulfo-Merthiolate'-preserved toxoid survived and 40 per cent of the guinea pigs immunized with 'Merthiolate'-preserved toxoid survived. The actual number of animals used in each of the final groups was, however, too small to make exact comparisons. It appears that further experimental biological preservation with 'Sulfo-Merthiolate' is indicated, inasmuch as its showing in toxoid is a good one.

## Discussion

The laboratory tests herein reported show that in biological action 'Sulfo-Merthiolate' (Sodium p-Ethyl Mercuri Thiophenylsulfonate, Lilly) is quite similar to 'Merthiolate' (Sodium Ethyl Mercuri Thiosalicylate, Lilly). Both compounds possess antibacterial action of about the same potency. Both have relatively low toxicity, in comparison with others of this class of drugs, when injected directly into the blood stream. There is almost complete freedom from protein precipitating qualities, and this germicide has a large margin of safety between undesirable toxic properties on the one hand and desirable antibacterial properties on the other hand.

The tests reported here, comprising evidence of both germicidal and strong bacteriostatic action as well as marked freedom from toxicity, are such as to indicate that 'Sulfo-Merthiolate' could exert a very pro-

TABLE VIII.—Comparative Immunizing Properties of Diphtheria Toxoid Preserved with 'Sulfo-Merthiolate' and Heated Two and Four Months at 37°C.

| Diphtheria Toxoid Number | Number of Months Heated | Results of immunity tests conducted by injecting toxoid-treated guinea pigs with different amounts of diphtheria toxin | | | | | |
|---|---|---|---|---|---|---|---|
| | | 10 MLD | | 20 MLD | | 40 MLD | |
| | | died | lived | died | lived | died | lived |
| B-4318A with 'Merthiolate' 1-10,000 | 2 | 2 | 2 | 0 | 4 | 1 | 3 |
| | 4 | 1 | 1 | 2 | 1 | 2 | 1 |
| B-4318B with 'Sulfo-Merthiolate' 1-10,000 | 2 | 1 | 3 | 2 | 2 | 4 | 0 |
| | 4 | 1 | 3 | 2 | 3 | 2 | 2 |

longed antibacterial action when used clinically. On the basis of nearly all newer knowledge of immunology and chemotherapy, a moderately strong and persistent antibacterial action would be more likely to be effective than strong initial germicidal action without any mechanism (bacteriostasis) to make this persistent. 'Sulfo-Merthiolate', soluble in both acid and alkaline pH ranges and having both germicidal and bacteriostatic action, could, therefore, be recommended for further clinical trial.

## Conclusions

1. A series of biological tests indicates 'Sulfo-Merthiolate' is a close counterpart of 'Merthiolate' in antiseptic action.

2. Concentrations of 1-2,000 to 1-3,000 of 'Sulfo-Merthiolate' are effective against staphylococci and typhoid bacilli when tested in blood serum.

3. Concentrations of 1-1,000,000 to 1-4,000,000 of 'Sulfo-Merthiolate' inhibit the growth of staphylococci and typhoid bacilli.

4. 'Sulfo-Merthiolate' in concentrations up to and including 1-200 does not precipitate serum. A 1-10,000 concentration is indicated as a biological preservative.

5. 'Sulfo-Merthiolate' in a concentration of 1-25 (i.e., forty times as strong as a stock 1-1,000 dilution) showed a beginning threshold of skin irritation.

6. White rats tolerate 40 to 50 mgm. 'Sulfo-Merthiolate' per kilo intravenously.

7. 'Sulfo-Merthiolate' is soluble over a wide acid and alkaline pH range.

## References

1. Powell, H. M., and W. A. Jamieson, 1931. Merthiolate as a germicide. Amer. Journ. Hyg. 13:296-310.

2. Jamieson, W. A., and H. M. Powell, 1931. Merthiolate as a preservative for biological products. Amer. Journ. Hyg. 14:218-224.

3. Powell, H. M., W. A. Jamieson, and G. F. Kempf, 1932. The healing properties of Merthiolate. Amer. Journ. Hyg. 15:292-297.

4. Morgan, L. C., W. A. Jamieson, and H. M. Powell, 1933. Merthiolate as a preservative for biological products. II. The production and preservation of diphtheria toxoid. Journ. Immunol. 25:121-126.

5. Powell, H. M., W. A. Jamieson, and F. G. Jones, 1933. Merthiolate as a preservative for biological products. III. Action of Merthiolate on bacteriophage. Journ. Immunol. 24:185-192.

6. Powell, H. M., and W. A. Jamieson, 1932. Comparative studies on Merthiolate with reference to laboratory evaluation and human tissue antisepsis. Proc. Indiana Acad. Sci. 41:249-256.

7. Powell, H. M., and W. A. Jamieson, 1933. Evaluation of antiseptics by test tube methods. Proc. Indiana Acad. Sci. 42:27-31.

8. Powell, H. M., and W. A. Jamieson, 1933. The influence of antiseptics on phagocytosis. Proc. Indiana Acad. Sci. 42:32-34.

9. Powell, H. M., and W. A. Jamieson, 1934. On Merthiolate and fungi associated with ringworm. Proc. Indiana Acad. Sci. 43:56-70.

10. Powell, H. M., and W. A. Jamieson, 1936. Maintenance of antiseptic action of Merthiolate as a preservative. Proc. Indiana Acad. Sci. 46:66-70.

11. Powell, H. M., and W. A. Jamieson, 1938. On the efficacy of Merthiolate as a biological preservative after ten years' use. Proc. Indiana Acad. Sci. 47:65-70.

('Merthiolate," included in the titles of papers in the foregoing references, is the trade-mark of Eli Lilly and Company for its sodium ethyl mercuri thiosalicylate.)

# Equine Encephalomyelitis

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Equine encephalomyelitis has been recognized as a virus disease of horses since 1931. In that year, Meyer, Haring, and Howitt (1), investigating an outbreak of cerebro-spinal disease among California horses, established the affliction as an infectious disease of virus origin. Previous to this time, many outbreaks, characterized by the same symptoms but of unknown etiology, had been reported. These early cases were referred to by a number of different names, some of the most common terms being Borna disease, forage poisoning, botulism, staggers, and cerebro-spinal meningitis. In 1912, 35,000 horses died as a result of an epizootic of a disease called "staggers," and, in 1919, Colorado alone lost almost 1,800 head to forage poisoning (2). It is now generally suspected that both of these epizootics were caused by the virus of encephalomyelitis. Forage poisoning, a disease caused by the consumption of moldy corn, does affect horses, but, unfortunately, the name has not been restricted to cases where toxic food is definitely involved. It is also true that botulism may affect horses, but these cases are rare and need not be confused with encephalomyelitis. Other bacterial and toxic infections of the brain and spinal cord would naturally lead to paralytic symptoms, somewhat resembling those of encephalomyelitis, but should not confuse one familiar with the latter disease. Virus diseases closely related to the American encephalomyelitis have been reported in Germany, France, and Russia, but all of these diseases are immunologically distinct.

In 1933 a disease very similar to that noted in California was reported as affecting horses in Virginia, Maryland, and Delaware (3). Except for a slight difference in incubation period and virulence, the outbreak was indistinguishable from that in the west. Records and Vawter (4, 5) found that in guinea pigs no cross immunity between the two could be demonstrated. Guinea pigs, injected with intranasally collected virus from horses suffering from the eastern disease, upon contracting the disease and surviving, were immune to a second injection of the same virus but succumbed to the western virus. In further experiments by these authors (4, 5), six out of eight horses immune to the western type also resisted the eastern type. These authors, therefore, decided that the chief difference in the virus of the two epizootics was one of virulence. However, Shahan and Giltner (3) and TenBroeck and Merrill (6), in 1933, published evidence that the eastern and western viruses were immunologically distinct. It has since been shown repeatedly that animals immune to the western virus are susceptible to infection by the eastern virus and that the reverse is also true. The disease is now known as eastern or western type encephalomyelitis in recognition of the two immunological types.

Typing tests which have been made by the Bureau of Animal Industries (7) and by investigators in private laboratories have shown

that the Appalachian Mountains form the dividing line between the eastern and western types of the disease. Until the summer of 1939, no case of infection with eastern type virus had been found west of this range, and no western type had been found east of the line. However, this summer Scofield reported a case of eastern type encephalomyelitis in Ontario, and the Bureau of Animal Industries reported another eastern type infection on an Alabama farm.

The causative virus of encephalomyelitis localizes its damage to the higher nervous centers of the brain and spinal cord. The symptoms of the disease are obviously the results of pathological changes in the brain and cord. The infection leaves practically no gross lesions, and only examination of nervous tissue yields evidence of specific pathological change. Hurst (8) made a study of the histopathology in horses and laboratory animals. The most striking microscopic lesions reported by him are: acute primary degeneration of nerve cells, nuclear inclusions in neurons, polymorphonuclear infiltration, especially in grey matter, and perivascular cuffing with mono- and polymorphonuclear cells. Eastern and western viruses cause the same changes, but the extent of damage is less in the case of western infection. In certain stages, the histopathology of the two types may be indistinguishable. A very intensive study of the histopathology of the nervous system in encephalomyelitis-infected guinea pigs has also been made by King (9). Histological changes and the histogenesis of the disease processes are described in detail.

The course of infection in encephalomyelitis is usually divided into three stages. During the first stage there is a rise in temperature, but other effects are so slight that this phase usually escapes detection in all but experimental cases. The second stage brings on the objective symptoms that result in the recognition of field cases. Infected animals show clearly the signs of nervous involvement with paralysis and incoordination apparent. The specific manner in which the disease manifests itself varies somewhat with individual horses, but typical symptoms are as follows: Normal skin irritability may give way to hypersensitiveness, or, at the other extreme, to complete lack of sensation. Partial or complete inappetence is often noted and grinding of the teeth, yawning, and twitching of various body muscles are common. In many cases there is a tendency to walk in circles. Later the animal becomes drowsy; this is so typical that the disease is widely known among the laity as "sleeping sickness." As paralysis and incoordination develop, the animal stands with feet spread wide or leans for support against stall partitions or fences. Occasionally, at the end of this second stage the animal manifests great excitement and irritability.

If the disease runs a fatal course, the third stage is that of complete incoordination in which animals are unable to stand but lie in a state of complete paralysis or thrash violently with running movements of the legs. This stage usually terminates quickly in death, but occasionally horses remain comatose for several days.

In small laboratory animals the usual symptoms are those of advancing paralysis, leading to coma and death. Mice and less often guinea pigs may suffer a convulsive spell just before the stage of pros-

tration. Since the intracerebral method of infection is the usual one in experimental cases, symptoms progress more rapidly and regularly than in field cases.

Diagnosis of field cases is made on the basis of the above clinical picture and the seasonal and epizootic character of the disease. Laboratory diagnosis, while an indispensable aid to research, is too slow for application to individual field cases. However, in investigating the possibility of spread into new areas or suspected out-of-season cases or in establishing the identity of the disease early in an epizootic, laboratory diagnosis is extremely useful. The slowest but surest means of diagnosing the disease is the inoculation of laboratory animals with brain tissue specimens from the suspected case, using normal animals and animals immune to both types of the virus. When such a group of animals is inoculated intracerebrally with a suspension of properly handled encephalomyelitis tissue, the normal animals and one group of immune animals will succumb. Such an immunological test leaves little question as to the identity of the disease and its type. A characteristic histopathology furnishes another means of laboratory diagnosis, but specimens for this test must be carefully handled and preserved, and the comparatively complicated and expensive procedure of tissue sectioning is necessary for reliable results. In recovered or suspected subclinical cases, neutralization tests with patients' serum and known virus often result in a reliable diagnosis.

The method by which the virus enters its natural host in the field is not definitely established. Kelser (**10**) has presented evidence that mosquitoes may carry the virus, and Merrill and TenBroeck (**11**) in 1935 published proof that *Aedes aegypti* can harbor the virus for a period of at least two months, provided it is fed a high concentration of the virus. Madsen and Knowlton (**12**) reported that several other species of the genus Aedes may carry the disease. However, there is no transmission of the virus between the male and female mosquitoes; nor are eggs and larvae from infected females or those grown in infected media dangerous as adults. The possibility of transmission by mosquitoes has been made more plausible by the demonstration of the virus in the blood stream of infected animals. The invasion of the blood stream by the virus is confined to a short period during the first temperature rise and just before the onset of objective symptoms. However, workers engaged in research for the United States Bureau of Animal Industries (**7**) have failed to detect virus in mosquitoes collected from epizootic areas. The obstacles in the way of anyone undertaking such experiments are great, and only positive results would be of great significance. There are still a great many who cling to the idea that an insect vector will some day be incriminated in the spread of encephalomyelitis. Those who believe in other methods of transmission have even less evidence in their support. It is unlikely that direct contact plays an important role for it is quite common for a few animals to contract the disease on the same premises where others in close contact remain healthy. While Records and Vawter (**5**) found virus in nasal washings of artificially infected horses, virus has not yet been detected in urine,

nasal washings, or even in nasal mucosa of naturally infected animals (13).

The path followed by the virus, once it gains entrance to the host, has not yet been completely worked out. It is easily demonstrated, however, that the virus invades the blood stream soon after its establishment in peripheral tissues. King (14) studied the pathogenesis of the disease and concluded that direct invasion of the brain from the blood stream seems to be the principal method of pathogenesis. Once in the nervous tissue, the virus may spread by different methods. In some cases affected regions bear a striking anatomical relationship; in other cases foci are joined by entirely unaffected anatomical connections. Thus the virus may travel along nerve connections or settle in several distinct areas simultaneously by deposition from the blood stream.

In addition to the problem of transmission during epizootics, we are faced with the question of how these epizootics start. It is one of the characteristics of equine encephalomyelitis that cases never occur after the first killing frost of the fall or before the warm weather of late spring. It is quite unlikely that horses themselves harbor the virus over this winter period. No success has met attempts to detect equine carriers of the virus. Furthermore, many horses are transferred from the eastern to the western zone, and vice versa, without disturbing the geographical distribution of the two types of virus. However, great progress is being made in the detection of other hosts to the virus. The disease has infected humans, monkeys, guinea pigs, mice and other laboratory animals, pheasants and pigeons, to name only a few possible hosts. Should it be proved that the occurrence of encephalomyelitis virus in migratory fowl is not a rare phenomenon, we shall be justified in closely associating birds with the epidemiology of encephalomyelitis. In this connection, susceptibility of human beings must not be overlooked. Outside of laboratory accidents, the source of infection in human cases is as mysterious as that of equine cases. A number of cases reported in Massachusetts in children were of unknown origin since there had never been any contact with horses or any other common source of the virus.

With so little known about the virus and its habits, it is quite natural that the treatment of encephalomyelitis is almost entirely symptomatic. The most important step in treatment, which acts directly against the virus, is the administration of antiserum of which more will be said later. Prerequisite to successful treatment is the provision of a quiet, restful atmosphere. Bright lights, noises, and all factors conducive to excitement are to be avoided. To combat dehydration, water must be administered. If no other way is possible, intravenous injections of water sometimes give good results. Harsh purgatives, because of the loss of water they cause, are contra-indicated, but mild laxatives are sometimes necessary and beneficial. Of course, the animal must be assisted in taking nourishment where paralysis has made chewing and swallowing difficult or impossible. These are the general lines of treatment. Many veterinarians have reported good results with various methods, but all such methods are based on the fundamentals of treating symptoms for immediate relief and injecting

serums to combat the virus. Some veterinarians are skeptical as to the therapeutic value of antiserum. It is true that, unless serum production is very carefully controlled, a product of low protective titre may result, but it is quite possible to produce a serum of high antibody content in animals in which, following vaccination, a state of hyper-immunity has been induced by the repeated injection of living virus. Previous to last year, the hyper-immunizing virus consisted of an emulsion of infected brain tissue. Antiserum produced by this method was of great value in treatment and prophylaxis but was still below the efficiency of antiserums of other diseases. With the development of the chick embryo propogated virus, an immunizing agent of far greater potency than was formerly possible has been made available. Chick embryo antigen contains as much as 100,000 times the virus concentration of brain tissue antigens. As a consequence of the greater stimulation of antibody mechanisms in serum-producing horses, anti-encephalomyelitis serum is now, at least in experimental trials, a far better prophylactic and therapeutic agent than it was a short time ago. The sudden dropping off of the incidence of encephalomyelitis this year has made impossible any field comparisons of the old and new serums, and it is consequently impossible to state how the new type serum will act in an actual epizootic. But it can be stated that in place of delicate neutralization tests protection tests are practical for titrating the new serum.

It is in the field of prevention that the greatest advances in the battle against encephalomyelitis have been made. To many the story of the development of a reliable vaccine in an almost incredibly short time is the most interesting phase of any consideration of the disease. Aside from the purely practical angle of saving horses' lives, the history of the vaccine is important because of the methods involved and because of new light shed on virus immunological problems during the investigations.

In 1934 Records and Vawter (**15**) published work on equine encephalomyelitis immunization through the use of active virus. They found subcutaneous injections of the virus would stimulate immunity but were extremely dangerous in that a great many animals succumbed to the disease during the process of immunization. Their attempts to inactivate the virus without disturbing the antigenic complex were unsuccessful. In the same year Howitt (**16**) also reported experiments designed to develop a safe yet efficient vaccine. She found that one small dose of live virus would immunize guinea pigs, but the same high incidence of infection followed vaccination that resulted in Records' experiments also occurred in the work of Howitt. Howitt also tried serum virus mixtures for vaccination. Practically no protection resulted from the injection of mixtures of serum and virus unless an excess of virus was present. It was also necessary to follow the initial serum-virus treatment with several injections of active virus. Although this method was safer than the former attempts of the author, the possibility of infection was still far too great to justify field use. In this connection it might be mentioned that Olitsky (**17**) in 1938 and Gochenour (**18**) in 1939 have published conclusive evidence that antiserum has a block-

ing effect on the action of vaccine. Gochenour advises against vaccination for a period of at least two weeks after administration of antiserum and presents experiments with guinea pigs to show that within this period prophylactic doses of serum prevent the action of vaccine.

In 1936 Olitsky and Cox (19) published a paper dealing with the quantitative aspects of vaccination with active virus. They found that active untreated virus, virus absorbed on aluminum gel, and virus precipitated by tannin were all equally efficient as immunizing agents and, furthermore, that 3000 to 30,000 m.i.d.'s of any of these agents were necessary to protect against intracerebral infection. Later in the same year, Olitsky (20), acting on the encouraging results reported by Shahon and Giltner (21), made a further investigation of the possibilities of formalized virus as a vaccine. He found that the method of preparing such vaccines was of great significance, and this may explain the failure of earlier attempts. Fresh tissues of high virus content, not over-formalized, gave consistently good results. Vaccine thus prepared has good protective and keeping qualities as long as the formalin is not neutralized.

Since the formalized virus was completely inactivated and the possibility of accidental infection nullified, field experiments were undertaken with success. As a consequence, a formalized brain tissue vaccine was produced by commercial houses and was used with gratifying but not complete success during the epizootics of 1937 and 1938.

In 1935 Higbee and Howitt (22) had succeeded in growing the virus of encephalomyelitis in the developing chick embryo, and Beard, et al, showed that both types of virus grew on this medium in greater concentrations than had hitherto been possible. It was then found that the chick embryo virus could be completely inactivated in the presence of 0.4 per cent formalin while retaining its antigenic integrity. Therefore, it became possible to make a vaccine which was not only entirely safe but, because of its high virus concentration, was extremely efficient. Guinea pigs inoculated with two doses of the chick embryo vaccine are solidly immune seventeen days or less from the time of the first inoculation. Guinea pigs so protected resist many lethal doses of the virus injected intracerebrally; unvaccinated controls invariably died.

Very briefly, the method of preparation of the chick vaccine is as follows. Fertile eggs incubated ten to twelve days make the best medium for propagation of the virus. A 20 per cent suspension of brain tissue virus may be inoculated by any of the accepted methods for virus propagation in eggs. The embryo is so susceptible to the virus, however, that there seems to be no need for natural or artificial air sac methods. If the virus is placed just beneath the shell of the egg, it will be in close enough contact to the chorioallantoic membrane so that infection and death will result in from 24 to 48 hours. Dead embryos harvested aseptically after the first virus passage and used in a 1 to 5 per cent suspension to inoculate other eggs will consistently cause death within 20 hours for an indefinite number of passages. After three or four egg passages, the virus has become adapted to the egg and fixed and is ready for use in the preparation of vaccine. Both the chick and its membranes are ground as finely as possible and suspended in physiological saline

solution. As is true of all tissue vaccines, the more thoroughly the chick tissue is ground, the more virus may be expected to be released into the diluent. Formalin sufficient to make a final concentration of 0.4 per cent may be added conveniently with the diluent. Forty-eight hours at room temperature is a safe time period to allow for inactivation of the virus, and at the end of this time the vaccine should immediately be refrigerated. Guinea pigs inoculated intracerebrally with the vaccine will serve to show the absence of any active virus. A potency test of satisfactory vaccine against a heterologous strain of the same type of virus should result in 100 per cent protection of principles and 100 per cent death of controls. A 1 to 500 dilution of guinea pig brain virus is the usual exposure dose in potency tests. Such a dose will bring complete prostration or death to controls in five days for the western virus and four days for the eastern virus.

With the new chick vaccine available, an important research tool has been added to the laboratory workers' collection. Studies on epidemiology, etiology, and immunology of the disease should advance more rapidly, now that a safe, sure method of immunization is known. It should be emphasized that the efficiency of the vaccine may prove important, not only in solving problems of equine encephalomyelitis but also in solving the fundamental problems of general virus immunology.

I should like, in conclusion, to mention that the study of the mechanism of immunity to encephalomyelitis is a fascinating research problem which is still to a great degree unsolved. It is quite natural that, in the face of costly and widespread epizootics, most research has been undertaken with a view to halting the spread of the disease. That objective is now well advanced toward accomplishment. The means of control of encephalomyelitis may be found in chick embryo vaccine if extensive vaccination can be practiced over a long period of time. But, in our haste to accomplish the practical end of saving horses' lives, we have to a great extent failed to inquire into the mechanisms of the results we have been able to bring about. For instance, we know that intracerebral exposure is more effective in causing fatal encephalomyelitis than any other method, and King (9) has shown that there is a difference in brain pathology in various types of inoculation. The reason for this difference needs more investigation. Olitsky has pointed out that antiserum is much less effective against intracerebral inoculation than intraperitoneal inoculation and mentions that, when virus enters nerve tissue, antiserum seems of little value. Yet, vaccinated animals resist incredibly strong doses of virus directly into the brain. Does this mean that actively immune animals are protected chiefly by tissue immunity? Does it also mean that serum from hyperimmunized animals protects other animals by destroying virus in the blood stream or at the point of inoculation? Such problems as these need more than philosophical consideration, and it is possible that chick embryo virus, with its ability to stimulate the production of more potent antiserum in hyperimmunized animals and a better active immunity in vaccinated animals, will lead to an experimental solution of many virus immunological problems.

## Bibliography

1. Meyer, K. F., C. M. Haring, and B. F. Howitt, 1931. The etiology of epizootic encephalomyelitis of horses in the San Joaquin Valley. Sci. 74:227.

2. Meyer, K. F., C. M. Haring, and B. F. Howitt, 1931. Newer knowledge of the neurotropic infections of the horse. Journ. Amer. Vet. Med. Assoc. N. S. 32:376.

3. Giltner, L. T., and M. S. Shahan, 1933. The 1933 outbreak of infectious equine encephalomyelitis in the eastern states. N. Amer. Vet. 14:25.

4. Records, E., and L. R. Vawter, 1934. Equine encephalomyelitis cross-immunity in horses between western and eastern strains of virus. Journ. Amer. Vet. Med. Assoc. 38:89

5. Records, E., and L. R. Vawter, 1935. Equine encephalomyelitis cross-immunity in horses between western and eastern strains of virus. Journ. Amer. Vet. Med. Assoc. 39:773.

6. TenBroeck and Merrill, 1933. (Cited in 7). Proc. Biol. and Med. 31:25.

7. Shahan, Giltner, and Schoening, 1938. A review of the 1938 outbreak of encephalomyelitis in the United States. Proc. U. S. Livestock Sanit. Assoc. 1938:157.

8. Hurst, E. W., 1934. The histology of equine encephalomyelitis. Journ. Exp. Med. 59:529.

9. King, L. S., 1938. Studies on eastern equine encephalomyelitis. I. Histopathology of the nervous system in the guinea pig. Journ. Exp. Med. 68:677.

10. Kelser, R. A., 1933. Mosquitoes as vectors of the virus of equine encephalomyelitis. Journ. Amer. Vet. Assoc. 35:767.

11. Merrill and TenBroeck, 1935. The transmission of equine encephalomyelitis by Aedes aegypti. Journ. Exp. Med. 62:687.

12. Madsen, D. E., and G. F. Knowlton, 1935. Mosquito transmission of equine encephalomyelitis. Journ. Amer. Vet. Med. Assoc. 39:662.

13. TenBroeck, Hurst, and Traub, 1935. Epidemiology of equine encephalomyelitis in the eastern United States. Journ. Exp. Med. 62:677.

14. King, L. S., 1939. Studies on eastern equine encephalomyelitis. II. Pathogenesis of the disease in the guinea pig. Journ. Exp. Med. 69:675.

15. Records, E., and L. R. Vawter, 1934. Equine encephalomyelitis immunization. Journ. Amer. Vet. Med. Assoc. 37:784.

16. Howitt, Beatrice F., 1934. Immunization of guinea pigs to the virus of equine encephalomyelitis. Journ. Infect. Dis. 54:368.

17. Cox, H. R., and P. K. Olitsky, 1936. Active immunization of guinea pigs with the virus of equine encephalomyelitis. IV. The effect of immune serum on antigenicity of active and inactive virus. Journ. Exp. Med. 64:223.

18. Gochenour, W. S., Jr., 1939. Effect of anti-encephalomyelitis serum on subsequent production of active immunity with encephalomyelitis vaccine. Journ. Amer. Vet. Assoc. 95:374.

19. Olitsky, P. K., and H. R. Cox, 1936. Active immunization of guinea pigs with the virus of equine encephalomyelitis. I. Quantitative experiments with various preparations of active virus. Journ. Exp. Med. 63:311.

20. Olitsky, P. K., and H. R. Cox, 1936. Active immunization of guinea pigs with the virus of equine encephalomyelitis. II. Immunization with formalized virus. Journ. Exp. Med. 63:745.

21. Shahan, M. S., and L. T. Giltner, 1935. Experimental studies on equine encephalomyelitis formalized brain tissue vaccine. N. Amer. Vet. 16:18.

22. Higbee, E., and B. Howitt, 1935. Journ. Bact. 29:399.

# BOTANY

Chairman: WINONA H. WELCH, DePauw University

The usual interest shown in the program of this section was maintained. About 70 to 75 were in attendance.

Ralph M. Kriebel, of the Soil Conservation Service, was elected chairman of the section for 1940.

## ABSTRACTS

**Dr. John Thomas Plummer, pioneer Indiana botanist.** LAWRENCE J. KING, Richmond.—Little notice has been given to the scientific work of an early physician of Richmond, Indiana, Dr. John Thomas Plummer (1807-1865). From an extensive search into the early scientific literature, it has been possible to construct a bibliography of approximately 145 titles. These papers cover many subjects from botany to philology. Some of his first writings were botanical, and these are among the earliest contributions to the flora of Indiana. An extensive biography is in preparation.

**Pteridophytes of the Lower Yangtze Valley.** CHARLES E. DE VOL, Indiana University.—This is a list of 154 species and varieties of pteridophytes collected over a period of six years. Keys, descriptions of genera, critical taxonomic notes, and Chinese names are given. The paper includes a brief history of Chinese pteridology and a digest of the literature. Two new species, *Athyrium Devollii* Ching and *Athyrium giganteum* De Vol, are described; *Monachosorum flagellare* (Max.) Hayata and *Hymenophyllum Wrightii* v.d.B. are reported from China for the first time; and twenty-two species new to the Lushan area are listed.

**A key to the ferns and fern allies of northeastern North America.** RAY C. FRIESNER, Butler University.—The appearance of Broun's *Index to North American Ferns* has done much to stabilize the nomenclature of this taxonomic group. So many new species, varieties, and forms are recognized that it is highly desirable that keys be constructed for their determination since there are none at present available except those scattered through periodical literature. The present key covers all species and varieties occurring within the range of Gray's *Manual.*

**The distribution in Indiana of *Quercus ellipsoidalis* E. J. Hill.** RALPH M. KRIEBEL, Bedford.—A study of the distribution of *Quercus ellipsoidalis* E. J. Hill has shown that it is definitely limited to that region of sand ridges, plains, and marshes in the northern part of the state where the substratum is sandy or gravelly and is now artificially drained. It is an inhabitant of the Plainfield soil types and is found more frequently on the heavier types of soil. Apparently, it is absent on the sand dunes around Lake Michigan but is a frequent to a common

tree in the sandy areas in the Kankakee Valley. It is mostly associated with *Quercus velutina* Lam. and *Quercus palustris* Muench. Specimens taken from two to eight trees from each of 18 counties are deposited in the author's herbarium, and duplicates of most of them were deposited in other herbaria in Indiana and in several of the larger ones outside of the state.

**A post-Pleistocene fossil pollen study of two northern Indiana bogs.** FRANK A. HAMP, Butler University.—The study deals with pollen analyses of the Lakeville and Round Lake bogs in deposits of late Wisconsin glaciation in northern Indiana. Both bogs show about the same successional record. Significant climatic changes from cool-moist to warm-dry are indicated by a striking decrease in Abies and Picea and appearance of numerous deciduous genera. The Lakeville bog showed a brief Pinus dominance in the 28-foot level which was absent in the Round Lake bog. Picea and Pinus persisted to the top foot level in both bogs. From the 27-foot level in the Round Lake bog and 26-foot level in the Lakeville bog, the forest dominance was essentially Quercus-Carya with a weaker co-dominance of Acer indicated in seven levels.

**Correlation of radii in asymmetrical growth of *Quercus velutina*.** RAY C. FRIESNER, Butler University.—Microscopic measurements of year ring growth made from 11 to 15 radii, each for four asymmetrical stump sections, 120 years old, of *Quercus velutina* show that there is a general gross correlation of growth increments, but the precise amount varies greatly. When all the radii of a particular section are compared for each year, we find 100% conformity for 8% to 10% of the years, 80% for 31% to 32% of the years, and 73% to 75% for 39% to 42% of the years. Conformity is greater in years of pronounced change. Curves plotted for successive radii of each individual year of growth show that growth follows a rhythmic pattern as the curve moves around any particular year. This is more pronounced in periods when annual growth increase is 2 mm. or more. External environmental factors play no recognizable role in determining asymmetrical growth.

**Formation of the perispore of the megaspore of *Isoetes Engelmanni*.** DOROTHY PARKER, St. Mary's College, Notre Dame.—The perispore of *Isoetes Engelmanni* is exogenous in origin. The formation involves an unusual multiplication of tapetal cells. The normal function of the tapetum is that of supplying food, but these cells go through a complicated process of division into morphological units which supply the megaspores with a perispore.

# History of Indiana Bryology

WINONA H. WELCH, DePauw University

Bryophytes are little studied in comparison with the spermatophytes, and the number of students interested in this group of plants is small. Indiana is fortunate in having had observations made and recorded in the field of bryology over a period of approximately 65 years.

The earliest published record of scientific interest in the bryophytes of Indiana, noted by the author, is that of Prof. A. H. Young[1] of Hanover College, Hanover, Indiana, in Botanical Gazette 2:61-62, 1876. Mr. Young states in this article that the mosses were collected during the fall and winter of 1875 and that he was assisted in the identifications by Prof. D. C. Eaton of Yale College and Mr. Eugene A. Rau of Bethlehem, Pennsylvania. The "Bryological Notes" prepared by Prof. Young concern 70 different species, collected in Jefferson county. The Young Herbarium of Bryophytes, consisting of several hundred packets, is in the Indiana University Herbarium.

Mrs. Mary Parry Haines,[2] a student of geology and paleontology, published two papers concerning the bryophytes of Wayne county, Indiana, in 1878 and 1879. I have had no success in locating the specimens upon which her publications were based.

Names of bryophytes from another portion of the state were published in 1879 by John Merle Coulter[3] in "The Flora of Northern Indiana". The Coulter specimens are in The Field Museum of Natural History.

Lucien Marcus Underwood,[4] in 1882, published a list of North American Hepaticae in which Indiana is represented. Probably L. M. Underwood, Professor of Botany in DePauw University, 1891-1895, is one of the most widely known American bryologists who has done extensive work with this group of plants in Indiana. Prof. Underwood was Director of the Botanical Division of the Indiana State Biological Survey of the Indiana Academy of Science and in 1893 had in his herbarium approximately 10,000 specimens of bryophytes, representing 900 species of mosses and 1,300 species of liverworts. In 1891, Prof. Underwood reported the finding of the rare moss, *Bryoxiphium norvegicum* (Bridel) Mitten in great abundance on the sandstone rocks of

[1]Born in Avondale, Cincinnati, Ohio, in 1852; died in Hanover, Indiana, in 1926. James L. White & Co. of New York published his biography in the National Cyclopedia of America in 1926.

[2]Born in Cinnaminson, New Jersey, Dec. 24, 1826; died at Richmond, Indiana, Dec. 8, 1884. Was custodian of the Paleontology Department of the Museum of the Scientific Association of Richmond, Indiana. Transactions of the Scientific Association of Richmond, Indiana, June 1, 1875. History of Wayne county, Indiana, 1884, page 187.

[3]Born in Ningpo, China, Nov. 20, 1851; died in Yonkers, New York, Dec. 23, 1928.

[4]Born in New Woodstock, New York, Oct. 26, 1853; died in Redding, Connecticut, Nov. 16, 1907. Curtis, Carlton Clarence, 1908. A biographical sketch of Lucien Marcus Underwood. Bull. Torrey Bot. Club 35:1-12. Barnhart, John Hendley, 1908. The published work of Lucien M. Underwood. Bull. Torrey Bot. Club 35:17-38.

Fern, Putnam county. The Indiana station was the fourth in the fourth state, Sullivant making the first report in 1846 for Ohio, Rau for Pennsylvania, and Mrs. Elizabeth G. Britton in 1883 for Wisconsin. Underwood also reported in 1891 the first collection in America of the hepatic, *Fossombronia cristata* Lindberg, having found it on clay banks at Fern. Among the 212 titles of the published works of Lucien M. Underwood, 31 concern Hepaticae. In nine of these, liverworts of Indiana are discussed. Prof. Underwood left only a small portion of his bryophyte collection in the DePauw University Herbarium. The Lucien M. Underwood Herbarium was purchased by The New York Botanical Garden.

In 1886, Bulletin I of the Purdue University School of Science contained the "Analytical Key to the Genera of Mosses, recognized in Lesquereux and James's Manual of the Mosses of North America," prepared by Charles Reid Barnes,[5] Professor of Botany, Purdue University, 1880-1885. Although the edition was large, the demand soon exhausted the supply of bulletins. Encouraged by these requests, in 1890 he published keys to the species of North American mosses recognized by Lesquereux and James. This edition was soon exhausted, and in 1896 Prof. Barnes published "Analytical Keys to the Genera and Species of North American Mosses." The taxonomic work of Prof. Barnes in the field of bryology won for him recognition among botanists. The analytical key was considered to be one of his most important publications on mosses. His specimens have been deposited in The Field Museum of Natural History and in the Herbarium of the University of Wisconsin.

Dr. W. S. Blatchley included a list of 13 species of mosses in his thesis concerning plants of Monroe county, in 1887.

Ellsworth Jerome Hill,[6] a teacher, minister, and botanist, collected extensively, leaving approximately 16,000 sheets in his herbarium, at the time of his death. Mr. Hill devoted his last 10 or 12 years to the study of mosses of the Chicago region. He prepared descriptions of 133 species. In the list of 162 titles of the E. J. Hill publications, there are 10 which concern bryophytes. Five of these articles discuss Indiana mosses and liverworts. The University of Illinois purchased the E. J. Hill Herbarium. Some of his mosses are also in the Herbarium of The Field Museum of Natural History.

Dr. Julius Röll, a foreign botanist, made extensive collections of mosses in America, in 1888, and many species of bryophytes collected in and near Hobart, Indiana, were published in his list in Hedwigia in 1893. Röll's collections of American mosses are in the Botanisches Museum, Berlin-Dahlem, Germany.

Prof. Joseph P. Naylor,[7] Head of the Physics Department of DePauw University for many years, was intensely interested in mosses, especially

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[5]Born at Madison, Indiana, Sept. 7, 1858; died in Chicago, Feb. 24, 1910. Anonymous, 1910. Charles Reid Barnes. Bot. Gaz. 49:321-324. Cowles, Henry C., 1910. Charles Reid Barnes. Science 31:(no. 797) 532-533.

[6]Born at LeRoy, New York, Dec. 1, 1833; died in Chicago, Ill., Jan. 22, 1917. Chase, Agnes, 1917. Rev. E. J. Hill. Rhodora 19:60-69.

[7]Born in Pennsville, Ohio, April 4, 1853; died in Little Rock, Arkansas, May 22, 1938. Edington, Will E., 1939. Joseph P. Naylor. Proc. Ind. Acad. Sci. 48:6-7.

those of Putnam county. Upon retiring from his college teaching, he presented his herbarium of several hundred packets and his bryophyte library of many volumes to the Botany Department of DePauw.

The bryophytes collected in Monroe county, Indiana, 1912-1914, by Prof. F. L. Pickett and Mrs. Mildred Nothnagel Wilson are in the Herbarium of Indiana University and in the personal collections of Prof. Pickett, Pullman, Washington, and Mrs. Wilson, Iowa City, Iowa.

Many of the contributions to Indiana bryology have been made in county studies as Jefferson, Wayne, Putnam, Steuben, Monroe, Hamilton, Marion, etc., or in specific localities as Spring Mill Park and the Dunes. Prof. Underwood, in 1894, presented to the Academy of Science the "List of cryptogams at present known to inhabit the state of Indiana."

A review of the bibliography of Indiana bryophytes shows that the studies first made were lists of species and varieties collected, with habitat notations; these were succeeded by morphological and physiological projects; and within the last few years many ecological problems have been carried on, contributing to the bryophytes more scientific importance than they have ever before received.

As a member of the Biological Survey Committee of the Indiana Academy of Science for several years, I have prepared a bibliography of Indiana bryophytes in addition to making extensive collections of mosses and liverworts of the state. In order that this bibliography may be available to others interested in bryophyte studies, I am including in this history of Indiana bryology a bibliography of Indiana bryophytes consisting of 81 references.

## Indiana Bryophyte Bibliography

Andrews, Albert LeRoy, 1913. Sphagnaceae. N. Amer. Flora **15**:7-9.

Andrews, F. M., 1923. Abnormal elaters of *Porella platyphylla*. Bull. Torr. Bot. Club **50**:85-87.

Andrews, F. M., 1925. An abnormal archegonium of *Funaria hygrometrica*. Bot. Gaz. **80**:337.

Andrews, F. M., 1908. An abnormal *Porella Platyphylla* Bot. Gaz. **45**:340.

Andrews, F. M., 1931. Liverworts of Spring Mill Park. Proc. Indiana Acad. Sci. 40:67-68.

Barnes, Charles R., 1886. Analytical key to the genera of mosses, recognized in Lesquereux and James's Manual of the Mosses of North America. Purdue Univ. Sci. Bull. **1**:1-12.

Barnes, Charles R., Dr. Brotherus, Dr. v. Venturi, F. Renauld, J. Cardot, J. Röll, and F. Stephani, 1893. Nord-Amerikanische Laubmoose, Torfmoose and Lebermoose gesammelt von Dr. Julius Röll in Darmstadt. Hedwigia **32**:181-214, 260-309, 334-402.

Blatchley, W. S., 1887. A thesis listing the plants of Monroe County, March, 1887, including a list of 13 species of mosses. (Pages not numbered.)

Bradner, E., 1892. A partial catalogue of the flora of Steuben county. Ind. Geol. Rept. **17**:135-159.

Britton, Elizabeth G., 1913. Bryoxiphiaceae. N. Amer. Flora **15**:69.

Clark, H. Walton, 1901. Flora of Eagle Lake and vicinity. Proc. Indiana Acad. Sci. **11**:128-192.

Cook, Mel. T., 1901. The vegetation of abandoned rock quarries. Proc. Indiana Acad. Sci. **11**:262-272.

Coulter, John Merle, 1879. The flora of northern Indiana. Bot. Gaz. **4**:109-113.

Daubenmire, Rexford F., 1929. Tufa deposits at Clifty Falls State Park. Proc. Indiana Acad. Sci. **38**:123-127.

Donaghy, Fred, 1916. The morphology of *Riccia fluitans* L. Proc. Indiana Acad. Sci. **25**:131-133.

Frye, T. C., 1928. Observations on the age of a few bryophytes. Bryol. **31**:25-29.

Glenn, Gail G., and Welch, Winona H., 1931. Ecological relationships of the most common mosses in a certain vicinity near Bloomington, Indiana. Proc. Indiana Acad. Sci. **40**:87-101.

Grout, A. J., 1936. Fissidentaceae. Dicranaceae. Moss Flora of North America north of Mexico **1**:22, 61.

Grout, A. J., 1935. Funariaceae. Moss Flora of North America north of Mexico **2**:73, 87.

Grout, A. J., 1931. Hypnaceae. Moss Flora of North America north of Mexico **3**:70.

Grout, A. J., 1932. Hypnaceae. Moss Flora of North America north of Mexico **3**:137, 148.

Grout, A. J., 1934. Leskeaceae. Fontinalaceae. Moss Flora of North America north of Mexico **3**:180, 242, 244, 246, 253.

Grout, A. J., 1924. Anthoceros. Mosses with a Hand-lens. Intelligencer Printing Co., Lancaster, Pa. P. 258.

Haines, Mary P., 1879. List of ferns, mosses, hepaticae, and lichens collected in Wayne county, Indiana. Rept. Geol. Sur. 8-**10**:235-239.

Haines, Mary P., 1876. Mosses and their uses. Trans. Ind. Hort. Soc. Pp. 68-72.

Haines, Mary P., 1878. Musci, Hepaticae, and Filices in vicinity of Richmond, Indiana. L. B. Case Bot. Index **1**:56.

Haupt, Arthur W., 1921. Gametophyte and sex organs of *Reboulia hemisphaerica*. Bot. Gaz. **71**:61-74, 446-453.

Haynes, Caroline C., 1920. Illustrations of six species of *Riccia*, with the original descriptions. Bull. Torr. Bot. Club **47**:279-287.

Hill, E. J., 1910. Charles R. Barnes and Julius Röll's collection of mosses in North America. Bryol. **13**:105-107.

Hill, E. J., 1916. *Fossombronia crispula* in the dune region of Indiana. Bryol. **19**:67-68.

Hill, E. J., 1917. List of his publications. Rhodora **19**:69.

Hill, E. J., 1916. Notes on Funaria. Bryol. **19**:35-37.

Hill, E. J., 1914. Notes on the distribution of *Polytrichum strictum* and some associated sphagna. Bryol. **17**:63-64.

Howe, Marshall A., 1923. Ricciaceae. N. Amer. Flora **14**:19.

Kurz, Herman, 1928. Influence of sphagnum and other mosses on bog reactions. Ecol. **9**:56-69.

Markle, M. S., 1918. A comparison of the plant succession on Hudson River limestone with that on Niagara limestone, near Richmond, Indiana. Proc. Indiana Acad. Sci. **27**:109-113.

Maximilian, Prince of Wied, 1906. Systematic view of the plants brought back from my tour on the Missouri, drawn up by Pres. Nees von Essenbeck, at Breslau. Thwaites Ed. **3**:343-344.

Mottier, David M., 1918. Chondriosomes and the primordia of chloroplasts and leucoplasts. Annals Bot. **32**:91-114.

Mottier, David M., 1894. Contributions to the life-history of *Notothylas*. Annals Bot. 8:391-402.

Mottier, David M., 1894. Contributions to the life-history of *Notothylas*. Proc. Indiana Acad. Sci. **4**:239.

Mottier, David M., 1891. Notes on the apical growth of liverworts. Bot. Gaz. **16**:141-143.

Parker, Dorothy, 1937. Some liverworts from Indiana. Bryol. **40**:79-80.

Petry, L. C., and M. S. Markle, 1911. An ecological survey of Whitewater Gorge. Proc. Indiana Acad. Sci. **20**:223-243.

Pickett, F. L., 1914. Notes on the survival of extreme drought by certain mosses. Bryol. **17**:94-95.

Pickett, F. L., 1915. Some mosses from Monroe county, Indiana. Bryol. **18**:33-34.

Pickett, F. L., 1925. The life history of *Ricciocarpus natans*. Bryol. **28**:1-3.

Pickett, F. L., and Mildred Nothnagel, 1913. The mosses of Monroe county. Proc. Indiana Acad. Sci. **22**:69-75.

Pickett, F. L., and Mildred Nothnagel, 1914. The mosses of Monroe county, II. Proc. Indiana Acad. Sci. **23**:103-105.

Pinnick, Atha A., 1925. On the number of chloroplasts in the cells of the sporophyte of *Anthoceros laevis*. Bull. Torr. Bot. Club **52**:515-518.

Pinnick, Atha A., 1926. On the number of chloroplasts in the cells of the sporophyte of *Anthoceros laevis*. Proc. Indiana Acad. Sci. **35**:185-188.

Potzger, J. E., 1939. Microclimate, evaporation stress, and epiphytic mosses. Bryol. **42**:53-61.

Röll, Julius, 1893. Nordamerikanische Laubmoose, Tordmoose und Lebermoose. Hedwigia **32**:181-214, 260-309, 334-402.

Röll, Julius, 1890. Vorläufige Mittheilungen über die von mir im Jahre 1888 in Nord-Amerika gesammelten neuen Arten und Varietäten der Laubmoose. Botanisches Centralblatt **44**:417-424.

Scott, Will., 1906. The Leesburg Swamp. Proc. Indiana Acad. Sci. **15**:209-226.

Showalter, Amos M., 1923. Studies in the morphology of *Riccardia pinguis*. Amer. Journ. Bot. **10**:148-167.

Taylor, Aravilla M., 1920. Appearance of mosses in ecological habitats. Bryol. **23**:81-85.

Taylor, Aravilla M., 1920. Ecological succession of mosses. Bot. Gaz. **69**:449-491.

Underwood, L. M., 1893. Index Hepaticarum. Part I. Bibliography Memoirs of the Torr. Bot. Club **4**:1-91.

Underwood, L. M., 1894. List of cryptogams at present known to inhabit the state of Indiana. Proc. Indiana Acad. Sci. **3**:30-67.

Underwood, L. M., 1882. North American Hepaticae, with a preliminary list of species for additions and corrections. Bot. Gaz. **7**:18-21.

Underwood, L. M., 1895. Notes on our Hepaticae. III. The distribution of the North American Marchantiaceae. Bot. Gaz. **20**:59-71.

Underwood, L. M., 1896. Notes on our Hepaticae. IV. The genus *Fossombronia*. Bot. Gaz. **21**:67-71.

Underwood, L. M., 1894. Report of the botanical division of the Indiana State Biological Survey. Proc. Indiana Acad. Sci. **3**:13-67.

Underwood, L. M., 1895. Report of the botanical division of the Indiana State Biological Survey for 1894. Proc. Indiana Acad. Sci. **4**:144-156.

Underwood, L. M., 1892. Some additions to the state flora from Putnam county. Proc. Indiana Acad. Sci. **1**:89-91.

Underwood, L. M., 1891. The distribution of the Hepaticae of North America. Proc. Amer. Assoc. Adv. Sci. **39**:298-304.

Van Gorder, W. B., 1885. Catalogue of the flora of Noble county, Indiana. P. 52.

Wareham, W. T., 1939. Pottiaceae. Grout, A. J., Moss Flora of North America north of Mexico **1**:200.

Welch, Winona H., 1929. A contribution to the phytoecology of southern Indiana with special reference to certain Ericaceae in a limestone area of the Bloomington Quadrangle. Proc. Indiana Acad. Sci. **38**:65-85.

Welch, Winona H., 1933. Ecological relationships of the most common mosses in a certain vicinity near Bloomington, Indiana. Bryol. **36**:11-13.

Welch, Winona H., 1934. Fontinalaceae. Grout, A. J., Moss Flora of North America north of Mexico **3**:242, 246, 253.

Welch, Winona H., 1937. Studies in Indiana bryophytes. Proc. Indiana Acad. Sci. **46**:72-78.

Welch, Winona H., 1938. Studies in Indiana bryophytes II. Proc. Indiana Acad. Sci. **47**:78-85.

Wilson, Betty L., 1936. A bryocenological study of some epiphytic mosses of a central Indiana woods. Butler Univ. Bot. Stud. **3**:149-172.

Wilson, Guy W., 1905. A travertine deposit in Tippecanoe county, Indiana. Proc. Indiana Acad. Sci. **15**:183-184.

Wilson, Guy W., 1894. Flora of Hamilton and Marion counties, Indiana. Proc. Indiana Acad. Sci. **4**:156-176.

Young, A. Harvey, 1876. Bryological notes. Bot. Gaz. **2**:61-62.

Young, Charlotte, 1938. Acidity and moisture in tree bark. Proc. Indiana Acad. Sci. **47**:106-114.

Yuncker, T. G., 1922. Additions and corrections to the list of Indiana mosses. Proc. Indiana Acad. Sci. **31**:155-156.

Yuncker, T. G., 1921. A handy method for the mounting of mosses. Bryol. **24**:43-44.

Yuncker, T. G., 1921. A list of Indiana mosses. Proc. Indiana Acad. Sci. **30**:231-242.

# The Centraalbureau voor Schimmelcultures of Baarn, Netherlands

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Since the middle of the nineteenth century when the science of plant pathology was born, the interest in the knowledge of fungi and the application of that knowledge to the control of plant diseases and to industrial applications has increased tremendously. The increasing amount of attention that is being given to mycology is evidenced by the rapidly growing volume of literature on the subject. This interest is not a local one but is world-wide, and every country of the world can boast its mycological experts.

Every institution in which fungi are objects of study carry a variable number of cultures. A few of the larger universities in the United States put these cultures in the hands of trained experts, but, in the majority of our institutions, the care of fungus cultures rests in the hands of poorly trained assistants or staff members, who have little time to give the critical attention which such organisms need if they are to retain their morphological characters, physiological potentialities, or even their viability. In such instances, in which the care is adequate, the number of fungi in culture are usually limited to those typical species that are used in classroom work or to other species that happen to be the objects of investigational research.

Every worker with fungi has realized the importance of established centers where any fungus might be obtained within a reasonable length of time and where he could expect such fungi to be cared for in such a reliable manner that their purity and viability would not be questioned. Such a center should be a repository also in which new strains or species or even new and interesting isolations of old species might be sent and maintained. Furthermore, an establishment of this sort would be of service in the verification of fungus species.

Though the United States has a large percentage of the active mycologists of the world, we do not have such a center for the care of fungus cultures as I have described.

The American Type Culture collection, now housed in the Georgetown University Medical School, Washington, D. C., offers to the mycologist the best service available in this country. Many species and strains of fungi are listed in this collection, and I can testify from personal experience that the cultures received from the American Type Culture collection are quite satisfactory. This collection, however, is primarily of interest to the bacteriologist and to the medical student, and the list is not as complete nor the service so all-embracing as it should be in order to interest the mycologist. Furthermore, the fungi that are listed have had their origin largely in this country among our own research workers. In no sense, may the American Type Culture collection be considered "international" in scope. These same criticisms

apply also to other but less ambitious collections of fungi extant in the United States.

There has been an advertisement carried in Phytopathology at intermittent intervals for the past several years, describing the services offered by the Centraalbureau voor Schimmelcultures at Baarn, Holland. Our scientific journals have carried brief notes concerning the work of this bureau and the collection maintained there, and the necessity for its support has been mentioned at some of the business meetings of the American Phytopathological Society.

Such meagre accounts as were available have always stimulated an interest because I was aware of the need of such a bureau. Last year when I was abroad on Sabbatical leave from Purdue, I determined that the Centraalbureau at Baarn should be one of my objectives. I, therefore, wrote to Dr. Joh. Westerdijk, requesting permission to visit her laboratories and to inspect the work of the Bureau. This request was graciously granted.

The Willie Commelin Scholten Phytopathological laboratory was founded in 1894 by Mr. and Mrs. Scholten Commelin, in honor of their son Willie, a student of biology, who died in 1894. This institute had a threefold purpose: (1) to give information in the practice of agriculture, horticulture and forestry, about diseases and their prevention; (2) to increase knowledge of plant diseases by research-work; (3) to promote the interests in instruction in phytopathology.

This laboratory was established in Amsterdam. In 1905, the government withdrew its financial support. In 1906, Dr. Johanna Westerdijk was appointed director of the laboratory, and, in 1917, she was appointed also Professor of Phytopathology at the University of Utrecht. Much of the practical work in plant pathology was done by Dr. Westerdijk's students in the laboratory of the Institute in Amsterdam. This laboratory soon became overcrowded. The congestion was relieved by an unexpected gift. Mr. A. Janssen, a retired tea planter, lived at Baarn, 13 miles from Utrecht. In the neighborhood of his mansion, Canton-Hall, he bought a plot of ground on which he had constructed conservatories and a gardener's lodge and laid out ornamental gardens with pinetum, kitchen garden, and orchard. In 1920, after the death of Janssen, this entire property was offered to the State of the Netherlands to be used in botanical instruction in the University of Utrecht. The former kitchen garden and the orchard are used for instruction in plant pathology by Dr. Westerdijk. The Willie Commelin Scholten Institute purchased a country house with grounds in the immediate neighborhood of Cantons-Park and removed from Amsterdam to Baarn in 1920. Dr. Westerdijk also retains a professorship in the University of Amsterdam. The Institute has become a center for investigational work by graduate students of the various universities of the Netherlands, as well as for occasional foreign students.

The Centraal Bureau for fungus cultures has been allotted space in the laboratories of the Willie Commelin Scholten Institute at Baarn.

The history of the Bureau began in 1905, at which time the Association Internationale des Botanistes decided to bring together a collection of pure cultures of fungi. Dr. Westerdijk eventually became director of

the collection. During the first World War, the International Association of Botanists ceased to exist. In order to provide funds to keep the collection in existence, several Dutch Scientific Societies provided the necessary funds. In 1918, the Royal Academy of Sciences in Amsterdam succeeded in obtaining a regular grant of money from the government for the Centraal Bureau. This academy also furnished support by issuing necessary publications, including the annual "list of fungi". The Bureau is also supported by the Section botanique of the Union internationale des Sciences biologiques. These various avenues of financial support are not sufficient to maintain the collection, and additional funds must be sought by the sale of cultures.

At the present time, a staff of four scientific workers is engaged in maintaining and extending the collection. One of these is constantly transferring and inserting newly obtained fungi; the other three have specialized in various groups of fungi. New species are regularly being published. The yeasts are being monographed, and other groups will be monographed as time and funds permit. A complete case record is kept of each fungus from the time it is received, and notations are made for each transfer. These records are filed. When a fungus is received, it is cultured to determine the purity of species, and a complete description of the fungus with sketches of spores and fruiting structures is kept as a part of the record. Before a culture is sent to a subscriber, it is first transferred and tested for purity by comparing it to the original descriptions. If for any reason a culture loses its viability or becomes atypical, it is discarded, but its record card is kept although transferred to another file.

The total number of cultures at the beginning of 1939 was 6,394. This number is increased each year by 400 to 500. Of course, a few are lost, but the total continues to increase annually. As the number of cultures carried by the Bureau increases, the value of this service to mycologists likewise increases. It must be apparent that the burden of expense also mounts. Additional room is required with this expansion. More expert assistance must be employed. An increased budget for media, glassware, and equipment is demanded. The available funds do not increase. The donations by the Dutch Scientific Societies and by the government of the Netherlands is probably now at a maximum. In fact, such sources of income will probably be less in the next few years because of the confused political situation in Europe.

The facts that have thus been presented would indicate that the continued usefulness of the Bureau is threatened unless mycologists everywhere and especially in the United States give it more effective support.

This support should come by seeing to it that the institutions to which we belong become subscribers to the collection.

A subscription of 60 guilders, about $33.00, entitles the organization subscribing to 50 cultures a year to be chosen from their printed lists.

A subscription of 30 guilders a year entitles one to select 20 cultures annually.

Cultures may be purchased individually without subscription at

the rate of two and one-half guilders per culture. Identifications are made for the same price.

Mycologists and plant pathologists may receive any culture in the list in exchange for one that they send which is not included in the published list.

Persons paying five guilders a year are considered to be donors.

The interest that is shown in fungi in this country, as may be indicated by the vast amount of published research, should cause mycologists to support eagerly the only elaborate clearing house for fungus cultures that is in existence.

# Notes on Indiana Grasses, 1938, 1939

J. E. Potzger, Butler University, and Chas. M. Ek, Kokomo

This is the seventh contribution of a series of annual reports on Indiana grasses previously unreported for the counties specified.

The nomenclature is that of Hitchcock's Manual of Grasses of the United States, 1935. The figures are J. E. Potzger's field numbers. Collections made by Ray C. Friesner are starred. All reports for Howard and Miami counties were made by Chas. M. Ek. A specimen of each grass reported here was deposited in the herbarium of Butler University.

*Aegilops cylindrica* Host., Howard (first report for the state). *Agropyron pauciflorum* (Schwein) Hitchc., Howard. *Agropyron repens* (L.) Beauv., Howard, Tipton, 8135. *Agropyron Smithii* Rydb., Howard, Miami, Tipton, *10650, Steuben, 7964. *Agrostis alba* L., Howard. *Agrostis hiemalis* (Walter) B.S.P., Bartholomew, *10581, Howard, Switzerland, 7936. *Andropogon furcatus* Muhl., Howard. *Andropogon scoparius* Michaux, Howard. *Aristida longespica* Poiret, Howard. *Aristida oligantha* Michaux, Howard. *Aristida purpurascens* Poiret, Clinton, 8265. *Brachyelytrum erectum* (Schreber) Beauv., Howard. *Bromus commutatus* Schrad., Grant, *10961, Howard, Switzerland, 7928, Warren, *11105. *Bromus inermis* Leysser, Fulton, 8149. *Bromus latiglumis* (Shear.) Hitchc., Howard. *Bromus japonicus* Thunberg, Howard. *Bromus purgans* L., Steuben, 7969, Warren, *11103. *Bromus secalinus* L., Howard, Ripley, 7919, Switzerland, 7938, Warren, *10969, Fulton, 8150. *Bromus tectorum* L., Warren, *10994. *Calamagrostis canadensis* (Michaux) Beauv., Grant, *10806, Hamilton, *10618, Howard, Miami, Tipton, *10639. *Cenchrus pauciflorus* Bentham, Howard. *Cinna arundinacea* L., Howard. *Cynodon Dactylon* (L.) Persoon, Howard, 8263. *Dactylis glomerata* L., Howard, Switzerland, 7926. *Danthonia spicata* (L.) Beauv., Howard, St. Joseph, 8158. *Diarrhena americana* Beauv., Howard. *Digitaris Ischaemum* Schreber, Howard, 8256. *Digitaria sanguinalis* (L.) Scopoli, Howard, Kosciusko, 8249, Tipton, *11713. *Echinochloa crusgalli* (L.) Beauv., Howard. *Eleusine indica* (L.) Gaertner, Howard, Miami, Tipton, *11739. *Elymus canadensis* L., Howard. *Elymus riparius* Wiegand, Howard, Miami. *Elymus villosus* Muhl., Switzerland, 7941. *Elymus virginicus* L., Howard, Jackson, *11685. *Eragrostis cilianensis* (Allioni) Link, Howard, 8260, Miami, Tipton, *11737. *Eragrostis frankii* Steudel, Kosciusko, 8242. *Eragrostis hypnoides* (Lamarck) B.S.P., Howard, 8266, Miami, 8267. *Eragrostis pectinacea* (Mx.) Nees, Howard, 8262, Tipton, *11736. *Eragrostis spectabilis* (Pursh) Steudel, Howard, Newton, 8037. *Festuca elatior* L., Howard, Ripley, 7921, Switzerland, 7932. *Festuca obtusa* Sprengle, Howard. *Glyceria septentrionalis* Hitchc., Howard. *Glyceria striata* (Lam.) Hitchc., Grant, *10807, Howard, Warren, *11026. *Hordeum jubatum* L., Grant, *10836, Howard, Warren, *11037. *Hystrix patula* Moench, Howard, Warren, *11097. *Leersia oryzoides* Swartz, Howard, St. Joseph, 8237. *Leersia virginica* Willd., Howard, 8168. *Muhlenbergia foliosa* Trinius, Howard. *Muhlenbergia mexicana* (L.) Trin., How-

ard. *Muhlenbergia Schreberi* J. F. Gmelin, Howard, Dearborn, *11753. *Muhlenbergia sobolifera* (Muhlenberg) Trin., Tipton, *11694. *Muhlenbergia tenuiflora* (Willd.) B.S.P., Howard. *Panicum clandestinum* L., Howard. *Panicum dichotomum* L., Switzerland, 7924. *Panicum dichotomiflorum* Michaux, Howard. *Panicum Gattingeri*, Nash, Kosciusko, 8241. *Panicum huachucae* Ashe, Allen, 7958, Blackford, *10936, Fulton, 8146, Howard, Hamilton, *10621, Noble, 8007, St. Joseph, 8163, Switzerland, 7925, Warren, *11012, Wells, *10910. *Panicum latifolium*, Mx., Fulton, 8148, Howard, Warren, *11084. *Panicum leibergii* (Vasey) Scribn., Tipton, *10651. *Panicum lindheimeri* Nash, Cass, 7940. *Panicum linearifolium* Scribn., Bartholomew, *10577a, St. Joseph, 8159, Steuben, 7974, Warren, *11067. *Panicum sphaerocarpon* Ell., Steuben, 7987. *Panicum microcarpon* Muhl., Cass., 7940. *Panicum Scribnerianum* Nash, Howard. *Panicum spretum* Schult., Cass, 7947. *Panicum virgatum* L., Howard, 8279, Ripley, *11792. *Panicum Werneri* Scribn., Montgomery, 8133, Warren, *11067. *Phalaris arundinacea* L., Howard. *Phleum pratense* L., Howard, Ripley, 7920, Switzerland, 7934. *Poa annua* L., Howard. *Poa compressa* L., Allen, 7960, Switzerland, 7939, Warren, *11002. *Poa palustris* L., Howard, Steuben, 7976. *Poa pratensis* L., Switzerland, 7927. *Setaria Italica* (L.) Beauv., Howard. *Setaria lutescens* (Weigel) Hubbard, Howard. *Setaria verticillata* (L.) Beauv., Cass, Howard. *Setaria viridis* (L.) Beauv., Howard, Warren, *10970. *Sorghastrum nutans* (L.) Nash, Howard. *Sorghum halepense* (L.) Persoon, Howard, Ripley, *11785. *Spartina pectinata* Link, Howard, Miami. *Sporobolus asper* (Michaux) Kunth, Howard. *Sporobolus cryptandrus* (Torr.) A. Gray, Newton, 8048. *Sporobolus neglectus* Nash, Howard, Tipton, *11715. *Sporobolus vaginaeflorus* (Torr.) Wood, Howard, Tipton, *11735. *Triodia flava* (L.) Hitchc., Dearborn, *11773, Howard, 8273.

# The Effect of Bacterial Contaminations Upon the Subsequent Growth of Fungi in the Same Medium

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The following investigation is the outgrowth of a laboratory accident. Using a Difco product, an assistant made a liter of potato dextrose agar. He failed to sterilize it immediately and permitted it to stand for 48 hours at room temperature in the unsterilized condition. When the medium was remembered eventually, it was found to be contaminated by a soft dirty white viscid bacterial growth that had developed on the surface at the point of contact between the medium and the glass of the flask.

Inasmuch as the medium was not to be used for any critical work, it was decided to sterilize it for thirty minutes and to use it in plates and tubes for the purpose of multiplying certain fungus cultures. Very much to our surprise, several species of fungi transferred to this contaminated, but sterilized medium, failed to grow.

We made an attempt to repeat the sequence of phenomena under controlled conditions. Since we had not anticipated that the bacterial contaminant would have any unusual powers, we had not isolated or saved it.

Potato dextrose agar was prepared according to the previous formula. The medium was permitted to stand unsterilized in cotton-stoppered flasks on laboratory shelves for 48 hours. At the conclusion of that period, a bacterial growth that seemed to be similar to the one in the previous accidental experiment appeared on the surface of the agar. As previously, this medium was sterilized for thirty minutes at fifteen pounds pressure. A liter of fresh uncontaminated potato dextrose agar was subjected to the same period of sterilization. The latter preparation was considered a check. Following the sterilization of the contaminated medium, the bacterial growth was no longer visible, and, since there was no subsequent growth of the contaminating organism, it was apparent that this agar was now sterile. The potato dextrose agar that had supported the bacterial growth was slightly darker and a trifle more cloudy than the check; otherwise, there was no apparent difference.

For the purpose of simplicity in the recording of results, the potato dextrose agar which was contaminated and then sterilized will be known as medium "A". The uncontaminated sterilized potato dextrose agar will be known as medium "B".

A transfer culture was made of the bacterial growth on medium "A" previous to sterilization and the organism was determined to be a member of the *B. subtilis* group. This organism was used as a 'staling' organism in all the subsequent experiments reported in this paper.

A series of plates was poured from each medium. The media were inoculated at the center of each plate with either *Diplodia zeae* or *Fusarium moniliforme*. Daily growth was indicated by ringing. Both

*F. moniliforme* and *D. zeae* covered the plates (90 mm. plates) of normal medium within 100 hours of inoculation, (Medium "B"). The growth made by *F. moniliforme* on medium "A", after the same amount of time had elapsed, was 20 mm., and, although the plates were permitted to stand until the agar had completely dried, no further growth was recorded. The total amount of growth made in medium "A" by *D. zeae* averaged a diameter measurement of only 8 mm. The growth made by both fungi on the uncontaminated medium was normal in every respect with a considerable development of aerial mycelium. The mycelial development in medium "A" exhibited few aerial hyphae and the individual hyphae were distorted, which is an indication of such sharp inhibition as is produced by staling.

In order to determine whether the bacterial contaminant was directly inhibitory to fungus growth, plates were poured with normal potato dextrose agar and inoculated in the center with either *F. moniliforme* or *D. zeae*. After an interval of 24 hours, in which time the fungus was well established on the medium, the bacterial contaminant was also planted near the periphery of the plate in which the fungus had begun growth. After another 24-hour interval, both fungus species exhibited the phenomena associated with inhibition and by 72 hours were sharply inhibited.

Cook[1] studied the results of fungi that succeeded each other in the same culture medium. He used a liquid synthetic medium, 'Cook's No. II liquid medium.' A mixture of this with a medium that had supported growth or a medium in which the fungus previously grown was made one of the constituents was used as test media. He also filtered out the fungus elements of growth, and this liquid was used instead of distilled water in making a new medium. On such media he grew a succession of fungi. In the medium made with the liquid from the filtered growth, he observed acceleration of growth. From this fact, Cook concluded that, if toxic substances were produced by fungus growth, they were not thermostable and were removed when the media were sterilized. He apparently ignored the fact that he was increasing the nutrient content of the medium by the methods that he used and that this increase might account for stimulated growth and might overcome the effect of any toxic inhibitory materials.

Our tests, which were repeated many times, indicate:

1. That a bacterial organism closely related to *B. subtilis* is capable of producing products in potato dextrose agar that are sharply inhibitory to both *Fusarium moniliforme* and *Diplodia zeae*.

2. That the materials so produced are stable to temperatures as high as 250°F. maintained over a period of 30 minutes.

3. That media that have been contaminated by certain bacterial organisms are incapable of supporting the normal development of some fungi. It is probably unsafe to use sterile media that have previously been contaminated in any critical studies with fungi.

4. Fungus-bacterial combinations are abnormal in probably every instance.

[1]Cook, Melville T., 1924. Succession of fungi on culture media. Amer. Journ. Bot. **11**:94-99.

# A Study of Certain Viruses Pathogenic to the Tomato[1]

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Fig. 1

Fig. 2

Fig. 1. Streak of tomato following artificial inoculation in greenhouse. Photographed March 2, 1916, at Lafayette, Indiana, by George Osner.

Fig. 2. Distortion and malformation of young leaves of tomato plant infected with virus A.

## Introduction

Winterblight or streak has been recognized as a transmissible virus disease of tomato in Indiana since 1916, (Fig. 1). It occurs mostly on greenhouse tomatoes, appearing in the initial stages as a necrotic spotting of the leaves and necrotic streaking of young stems and petioles. The tips of shoots are frequently killed. Subsequent symptoms are conspicuous mottling, distortion and malformation of leaves that develop subsequent to the necrotic phase, and stunting of the plants. Once the disease starts in a greenhouse planting, it usually spreads rapidly. Crop loss is complete if the disease develops before the tomato plants have attained any size or set much fruit.

As has been repeatedly demonstrated, this disease may be produced by a combination of the virus of tobacco mosaic (Johnson's tobacco virus 1 (23)) and a virus present in all tubers of many American varieties of potatoes (Johnson's tobacco virus 5 (23)). As considered here, it is essentially a double-virus disease in which the two viruses act in com-

[1]Based upon a thesis submitted by R. W. Samson to the Faculty of Purdue University in partial fulfillment of the requirements for the Degree of Doctor of Philosophy, June, 1932.

The writer wishes to acknowledge his indebtedness to Doctor M. W. Gardner for advice and assistance.

plementary fashion to cause a more destructive disease than either virus alone will produce. This property of complementary action has been used by the writer to separate a number of viruses into two opposing groups. Each member of one group is complementary to the potato virus so far as its streak-producing property is concerned. The tobacco mosaic virus is a typical example of this group. Each virus of the second group is complementary to the tobacco mosaic virus. The virus from apparently healthy plants of many old American potato varieties is a typical example. For convenience, the first group is referred to as the virus A group, and the second as the virus B group.

The purpose of this paper is to present references to the pertinent literature and a brief account of some studies by the writer on the symptoms, host range, and properties of two viruses of the B group involved in the tomato streak complex.

### Literature on the Double-Virus or Streak Disease of Tomato

The earliest reference that the writer has found to tomato streak is apparently in Plowright's writings of 1887 (28). The following workers, listed in chronological order from 1888 to 1931, also report work on the streak or winter-blight disease: Galloway (11), Lodeman and Bailey (3), Selby (37), Clinton (7), Orton and McKinney (27), Howitt and Stone (18), Gardner and Kendrick (13), Gardner (12), Dickson (8), Johnson (21, 22), Vanterpool (43), Gardner and Kendrick (14), Blood

Fig. 3

Fig. 4

Fig. 3. Jimson weed plant 23 days after inoculation with virus B, showing sequence of vein-clearing on older leaves, transverse bands of mild chlorosis and vein-banding on next younger and still younger leaf tissues, respectively, and irregular mottling barely visible on the younger leaves.

Fig. 4. Jimson weed plant 17 days after inoculation with the Jimson weed strain of virus B, showing the more severe disease produced by this virus.

(5), Berkeley (4), Stover (39), J. Henderson Smith (17), Jarrett (19), Doolittle and Blood (9), Valleau and Johnson (40, 42.)

Clinton (7) probably was first to report artificial transmission of the disease. Vanterpool (Dickson, 8) and Johnson (21, 22) demonstrated its duplex nature. Gardner and Kendrick (14) showed by inoculation tests that it is produced by a combination of the tobacco mosaic virus and the virus present in apparently healthy potato plants, namely the virus of Fernow's mosaic B (10) and herein designated as virus B.

### The Virus A Group

The strain of tobacco mosaic used for most of these studies with references made as virus A exhibited the properties of Johnson's tobacco virus 1 (23) such as resistance to drying, ageing, heat, dilution, and chemicals and produced typical tobacco mosaic symptoms on tobacco (1, 15) and tomato (13), (Fig. 2). In addition, a number of viruses were collected in tomato fields which gave strikingly different symptoms when inoculated into tomato alone but which produced typical tomato streak when combined with a B virus. That there should be a number of viruses of the A type is evident from the work of Henderson Smith (16), Jarrett (19), and Valleau and Johnson (40).

### The Virus B Group

The individual viruses of the B group are characterized by their complementary action in the production of tomato streak when combined with virus A. Two in particular are of concern here. The first is evidently the one which has been referred to by other workers as the mottle or ringspot virus (22), healthy potato virus (41), mosaic B (10), and latent virus (6). The symptoms produced on tomato by the virus used in most of the writer's experiments compare best with those described by Burnett and Jones (6) as produced by their latent potato virus. On tobacco it has produced symptoms most comparable with Johnson's mottle virus. On Jimson weed (Fig. 3) it produces symptoms most like those figured by Fernow for his mosaic B.

The second virus was originally collected from a wild Jimson weed. It is more virulent than the potato virus and is best distinguished from the latter by the much more severe disease it produces on Jimson weed (Fig. 4) and *Nicandra physalodes*. When combined with virus A, it produces typical streak, thus marking it as a virus of the B group.

**Literature on the virus B group.**—Many workers have transmitted or attempted to transmit potato virus diseases to tomato. The following papers may be mentioned: Johnson (22, 23), Quanjer (29), Schultz and Folsom (35), Olitsky and Northrop (26), Fernow (10), Vanterpool (43), E. M. Johnson (20), Valleau and Johnson (41), Koch (25), Burnett and Jones (6). The following viruses have been described from apparently healthy potatoes: Virus of mosaic B (Fernow), spot necrosis and ringspot (Johnson), veinbanding and healthy potato (Valleau and Johnson), and latent and virulent latent (Burnett and Jones). Johnson's spot necrosis has been split into a mottle virus and an insect-transmitted virus by Koch. The veinbanding virus is probably the same as Koch's

insect-transmitted virus. Valleau and Johnson and Burnett and Jones were unable to produce streak in tomato by combining it with virus A. The ringspot virus is apparently the same as Valleau and Johnson's healthy potato virus and Burnett and Jones' virulent latent virus. All of the above viruses, except that of veinbanding, appear to have a factor in common which combines with virus A to produce streak in tomato. Fernow's description of his mosaic B and Johnson's description of his mottle virus appear to fit this common factor which is designated here as virus B.

**Symptoms produced by virus B.**—Goldstein (15) has described a series of leaf symptoms that appear consistently on tobacco plants inoculated with the tobacco mosaic virus. An analogous set of symptoms is produced by virus B on tomato, Jimson weed, and tobacco. They appear on Jimson weed (Fig. 3) as veinclearing on the older leaves, general chlorosis with green islands on next younger tissue, and veinbanding on still younger tissue. Each of these more or less transverse bands of symptoms grades into the other with no sharp line of demarcation. All leaves that develop subsequent to those that show the veinbanding show irregular chloritic areas between the major veins. The same sequence of symptoms develops on tomato and tobacco plants infected with virus B but is not so obvious.

**Susceptibility of species and varieties of the Solanaceae to virus B.**—Virus B was inoculated into the following 20 species and varieties of the Solanaceae: *Browallia elata* L.; *Capsicum frutescens* L., var. *Cayenne; Datura stramonium* L., (Jimson weed); *Lycopersicon esculentum* Mill., var. *Greater Baltimore; Lycopersicon pimpinellifolium* Mill.; *Nicandra physalodes* (L.) Pers.; *Nicotiana alata* Link and Otto, var. *longiflora; N. Sanderae* Sanders; *N. sylvestris* Spegaz, and Comes; *N. tabacum* L.; *Petunia hybrida* Vilm., vars. *Calif. Giant* and *Gen. Dodds; Physalis Alkekengi* L.; *P. pubescens* L.; *P. subglabrata* Mackenzie and Bush.; *Solanum carolinense* L.; *S. Melongena* L., vars. *Black Beauty* and *Neapolitan; S. nigrum* L.; *P. pseudocapsicum* L.; *S. tuberosum* L. (seedlings). It was recovered in apparently unaltered form from nineteen of the twenty. *S. pseudocapsicum* was not infected.

Mottling was produced on all plants from which the virus was recovered except for certain potato seedlings which showed no symptoms. Necrosis was produced on *N. physalodes*, pepper, and certain potato seedlings. The virus was recoverable only from the necrotic lesions of potato seedlings showing no other symptoms. It was recovered readily from the necrotic lesions on cayenne pepper but only occasionally from other parts of such infected plants.

**Properties of virus B.**—Virus B remained infectious after storage for 87 days in Jimson weed juice in the refrigerator and for 47 days at room temperature. In one test, virus B in tomato juice was still infectious after dilution to 1:10,000 but not 1:100,000. The inoculum was applied to the test plants with the broken point of a small glass pipette. The virus withstood drying for 16 days in Jimson weed leaves but not for 18 months. It survived heating at 61°C. for ten minutes but not 70°C.

**Symptoms produced by the Jimson weed strain of virus B.**—The striking symptoms produced by the virus from Jimson weed on tomato, Jimson weed (Fig. 4), certain species of tobacco, and *Nicandra physalodes* and the fact that it combines with virus A to produce streak have made it of special interest. The sequence of development of symptoms produced by this virus is much the same as that for virus B from potato, but the ultimate effects of the virus are much more severe. Clearing of the veins on the older leaves is quickly followed by a necrosis of the cleared veins, with necrosis extending into the interveinal areas. The general chlorosis of the next younger tissue is quickly followed by extensive necrosis of this same zone, producing a burned or scorched effect. Marked interveinal chlorosis and veinbanding develop on the next younger leaves with some necrotic spotting and rugosity. All leaves that develop later than these are coarsely mottled and more or less cupped, puckered, or savoyed.

**Host range and properties of the Jimson weed strain of virus B.**—The Jimson weed virus was used for inoculation and recovered unchanged from the same series of solanaceous hosts as virus B. The severity of the disease produced on Jimson weed, *Nicandra physalodes* and *Nicotiana alata*, in particular, served to differentiate it from virus B. The virus was infectious after 87 days storage in Jimson weed juice in the refrigerator and after 16 days drying in Jimson weed and tomato leaves. It withstood heating at 75°C. for ten minutes, being more resistant to heat than virus B, and was infectious at a dilution of 1:10,000 but not 1:100,000.

## Separation of the Component Viruses of Tomato Streak

In the course of the limited host range studies with the three viruses of concern in this paper, it was found that certain hosts could be used to separate out the viruses present in the streak complex. Virus A could be recovered only from the necrotic lesions on Jimson weed and certain potato seedlings inoculated with this virus. It was recovered from necrotic lesions on inoculated Black Beauty eggplant *(Solanum melongena)* and only occasionally from non-necrotic parts. It could be recovered from most portions of infected pepper plants. The B virus, on the other hand, could be recovered from all parts of Jimson weed plants inoculated with these viruses and from symptomless or mottled parts of the potato seedlings used in the studies. It was found possible to recover either B virus from Jimson weed or potato seedlings inoculated with streak. Virus A could be recovered from pepper inoculated with streak. The entire streak complex was sometimes recovered from non-necrotic parts of both Black Beauty eggplant and pepper. It appears that virus A invades this eggplant less extensively than the B viruses and that the latter do not become systemic in pepper to the same extent as virus A.

## Summary

A number of viruses or strains of viruses of the tobacco mosaic group occur on canning tomatoes in Indiana. This conclusion is based on symptoms produced by various collections of these viruses and by their

complementary action with the so-called healthy potato virus or virus B in the production of tomato streak. Likewise, it appears that there are a number of viruses and strains of the virus B group, two of which are described in some detail. The differences in the extent to which the viruses of these two groups invade Jimson weed, Black Beauty eggplant, certain potato seedlings or clones, and pepper provide a means of their separation from a streak complex. The variety of forms and relative abundance of these viruses as they occur in Indiana justify additional investigations now under way.

## Literature Cited

1. Allard, H. A., 1914. The mosaic disease of tobacco. U. S. Dept. Agric. Bull. **20**:1-33.

2. Atanasoff, D., 1925. New studies on stipple streak disease of potatoes. Phytopath. **15**:170-177.

3. Bailey, L. H., 1892. Some troubles of winter tomatoes. Cornell Univ. Agric. Exp. Sta. Bull. **43**:149-158.

4. Berkeley, G. H., 1927. Studies in tomato streak. Sci. Agric. **7**:210-223.

5. Blood, H. L., 1928. A "streak" of tomatoes produced by a disturbing principle from apparently healthy potatoes in combination with tomato mosaic virus. Phytopath. **18**:311.

6. Burnett, Grover, and Leon K. Jones, 1931. The effect of certain potato and tobacco viruses on tomato plants. Wash. Agric. Exp. Sta. Bull. **259**:1-37.

7. Clinton, G. P., 1914. Chlorosis of plants with special reference to calico of tobacco. Conn. Agric. Exp. Sta. Ann. Rept. **1914**:357-424.

8. Dickson, B. T., 1925. Tobacco and tomato mosaic. Sci. **62**:398.

9. Doolittle, S. P., and H. L. Blood, 1930. Investigations of tomato streak. Phytopath. **20**:134.

10. Fernow, Karl Hermann, 1925. Interspecific transmission of mosaic disease of plants. Cornell Univ. Agric. Exp. Sta. Memoir **96**:1-34.

11. Galloway, B. T., 1889. Report of the section of vegetable pathology. Rept. Com. of Agric. **1888**:325-404.

12. Gardner, Max W., 1925. Necrosis, hyperplasia, and adhesions in mosaic tomato fruits. Journ. Agric. Res. **30**:871-888.

13. Gardner, Max W., and James B. Kendrick, 1922. Tomato mosaic. Purdue Univ. Agric. Exp. Sta. Bull. **261**:1-24.

14. Gardner, Max W., and J. B. Kendrick, 1927. Potatoes a virus disease menace to tomatoes. Hoosier Horticul. **9**:5-8.

15. Goldstein, Bessie, 1926. A cytological study of the leaves and growing points of healthy and mosaic diseased tobacco plants. Bull. Tor. Bot. Club **53**:499-599.

16. Henderson Smith, J., 1928. Experiments with a mosaic disease of tomato. Ann. Appl. Biol. **15**:155-167.

17. Henderson Smith, J., 1928. The transmission of potato mosaic to tomato. Ann. Appl. Biol. **15**:517-528.

18. Howitt, J. E., and R. E. Stone, 1916. A troublesome disease of winter tomatoes. Phytopath. **6**:162-166.

19. Jarrett, Phyllis H., 1930. Streak—a virus disease of tomatoes. Ann. Appl. Biol. **17**:248-259.

20. Johnson, E. M., 1930. Virus diseases of tobacco in Kentucky. Ky. Agric. Exp. Sta. Bull. **306**:289-415.

21. Johnson, James, 1925. A virus from potato transmissible to tobacco. Phytopath. **15**:46.

22. Johnson, James, 1925. Transmission of viruses from apparently healthy potatoes. Wisc. Agric. Exp. Sta. Res. Bull. **63**:1-12.

23. Johnson, James, 1927. The classification of plant viruses. Wisc. Agric. Exp. Sta. Res. Bull. **76**:1-16.

24. Johnson, James, 1929. The classification of certain virus diseases of the potato. Wisc. Agric. Exp. Sta. Res. Bull. **87**:1-24.

25. Koch, Karl, 1931. The potato rugose mosaic complex. Sci. **73**:615.

26. Olitsky, P. K., and H. H. Northrop, 1925. The inoculation of tomato and tobacco plants with potato mosaic virus. Sci. **61**:544-545.

27. Orton, C. R., and W. H. McKinney, Jr., 1915. Winter blight of the tomato. Ann. Rept. Pa. Agric. Exp. Sta. **1914-15**:235-246.

28. Plowright, Charles B., 1887. Tomato disease. Gard. Chron. III. **1**:532.

29. Quanjer, H. M., 1923. General remarks on potato diseases of the curl type. Rept. Int. Conf. Phytopath. and Ent. **1923**:23-28.

30. Quanjer, H. M., 1931. The methods of classification of plant viruses, and an attempt to classify and name potato viruses. Phytopath. **21**:577-613.

31. Salaman, Redcliffe N., 1930. Crinkle "A", an infectious disease of the potato. Proc. Roy. Soc. London, Ser. B. **106**:50-83.

32. Salaman, Redcliffe N., and Richard H. LePelley, 1930. Para-crinkle: a potato disease of the virus group. Proc. Roy. Soc. London, Ser. B. **106**:140-175.

33. Samuel, Geoffrey, 1931. Some experiments on inoculation methods with plant viruses, and on local lesions. Ann. Appl. Biol. **18**:494-507.

34. Schultz, E. S., 1925. A potato necrosis resulting from cross inoculation between apparently healthy potato plants. Sci. **62**:571-72.

35. Schultz, E. S., and D. Folsom, 1923. Transmission, variation and control of certain degeneration diseases of Irish potatoes. Journ. Agric. Res. **25**:43-115.

36. Schultz, E. S., and Donald Folsom, 1925. Infection and dissemination experiments with degeneration diseases of potatoes. Journ. Agric. Res. **30**:493-528.

37. Selby, A. D., 1896. Investigations of plant diseases in the forcing house and garden. Ohio Agric. Exp. Sta. Bull. **73**:221-246.

38. Smith, Kenneth M., 1931. On the composite nature of certain potato virus diseases of the mosaic group as revealed by the use of plant indicators and selective methods of transmission. Proc. Roy. Soc. London, Ser. B. **109**:251-267.

39. Stover, W. G., 1928. Experiments with tomato streak. Phytopath. **18**:154.

40. Valleau, W. D., and E. M. Johnson, 1930. Some possible causes of streak in tomatoes. Phytopath. **20**:831-839.

41. Valleau, W. D., and E. M. Johnson, 1930. The relation of some tobacco viruses to potato degeneration. Ky. Agric. Exp. Sta. Bull. **309**:475-502.

42. Valleau, W. D., and E. M. Johnson, 1931. The viruses concerned in a natural epiphytotic of streak in tomatoes. Phytopath. **21**:1087-1089.

43. Vanterpool, T. C., 1926. Streak or winter blight of tomato in Quebec. Phytopath. **16**:311-331.

# New Agaricaceae of the Chicago Region

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In 1909, Moffatt (15) reported 210 species of Agaricaceae that were collected in the "Chicago Region" (an area of about 1800 square miles around Chicago, Illinois) over a period of several years. Graham (8, 9, 10) added to this list between 1927 and 1933. His additions increased the number of Agaricaceae to 256 species and varieties distributed among 47 genera. The writer, while collecting Agarics in 1935, chiefly near Evanston, Illinois, which is near Chicago, found 109 species and varieties. Of this number 41 have not been reported from the Chicago Region. The addition of the 41 reported here gives a total of 297 species and varieties distributed among 48 genera for the designated area.

The writer has tried to determine the correct authority for the name of each new species reported. As a guide he has used the International Rules of Botanical Nomenclature of 1930 (1). It has seemed better not to refer to any pre-Friesian author in the author citation. Moreover, he has spelled the specific names as they were first spelled when the species were described except in those cases where the specific name did not agree in gender with the generic name. In the case of those species of recent description, the author citation is the one used by Kauffman (14).

The specimens are in the herbarium of the writer.

The additions to the list of Agaricaceae of the Chicago Region are as follows: *Agaricus Rodmani* Peck, *Amanita bisporiger* Atkinson. *A. mappa* (Fries) Quélet (1872), *Amanitopsis parcivolvata* Peck, *Bolbitius fragilis* Fries (1836-1838), *Cantharellus cinnabarinus* Schweinitz, *Clitocybe odorus* (Fries) Quélet (1872), *Coprinus ebulbosus* Peck, *C. lagopus* Fries (1836-1838), *C. quadrifidus* Peck, *C. radians* Fries (1836-1838), *C. stercoreus*[1] Fries (1836-1838), *Cortinarius semisanguineus* (Fries) Gillet (1874), *Hypholoma hydrophilum* Fries (1836-1838), *H. incertum* Peck, *H. incertum* var. *sylvestre* Kauffman (1918), *H. sublateritium* (Fries) Quélet (1872)[2] var. *perplexum* Peck, *Lactarius camphoratus* Fries (1836-1838), *L. chrysorheus* Fries (1836-1838), *L. ligniotus* Fries 1857), *L. volemus* Fries (1836-1838),[3] *Lepiota coerulescens* Peck, *Marasmius capillaris* Morgan, *M. delectans* Morgan, *M. glabellus* Peck, *M. glabellus* var. *bellipes* Morgan, *M. magnisporus* Murrill, *M. ramealis* Fries (1836-1838), *M. resinosus* (Peck) Saccardo, *M. scorodonius* Fries (1836-1838), *M. semihiritipes* Peck, *Panus rudis* Fries (1836-1838), *Pholioto unicolor* (Fries) Quélet (1872), *Pleurotus circinatus* (Fries) Gillet (1874),[2] *P. fimbriatus* (Fries) Gillet (1874)[2] var. *regularis* Kauffman, (1918), *Pluteus cervinus* (Fries) Quélet (1872) var. *albus* Peck,

[1]Commonly spelled *C. stercorarius* Fries.

[2]This author citation was kindly furnished by Dr. Alexander H. Smith of the University of Michigan.

[3]Frequently called *Lactaria lactiflua* (L.) Burlingham.

*Psilocybe arenulina* Peck, *Russula chamaeleontina* Fries (1836-1838), *R. foetens* Fries (1836-1838), *R. fragilis* Fries (1836-1838), *R.* sp.[1]

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The writer wishes to thank Dr. A. E. Edgecombe of Northwestern University for his aid and guidance during the collection and identification of the fungi. He also wishes to express appreciation to Dr. E. A. Bessey of Michigan State College for his help and counsel during the determination of the authorship of the various species and the preparation of this paper. Dr. Alexander H. Smith and Dr. Gertrude S. Burlingham have also aided in certain problems of authorship of species.

## Bibliography

1. Briquet, John, 1935. International rules of botanical nomenclature. Jena.
2. Fries, Elias, 1821. Systema mycologicum **1.**
3. Fries, Elias, 1828. Elenchus fungorum.
4. Fries, Elias, 1836-38. Epicrisis systematis mycologici.
5. Fries, Elias, 1857. Monographia hymenomycetum sueciae.
6. Fries, Elias, 1874. Hymenomycetes Europaei. 2nd ed.
7. Gillet, C. C., 1874. Les hymenomycetes.
8. Graham, V. O., 1927. Ecology of fungi in the Chicago Region. Bot. Gaz. **83**:267-287.
9. Graham, V. O., 1933. Mushrooms of the Chicago Region. Chicago Acad. Sci. 4(3):42-62.
10. Graham, V. O., 1932. The genus Hygrophorus in the Chicago Region. Ill. Acad. Sci. **23**:160-168.
11. Karsten, P. A., 1879, 1882. Rysslands, Finlands, och den Skandinaviska Halfons Hattsvampar. Bidrag till Kännedom af Finlands Natur och Folk **32**:1-28, 1-550; **37**:5-19, 1-245.
12. Karsten, P. A., 1889. Kritisk öfversigt af Finlands Basidsvampar. Bidrag till Kännedom af Finlands Natur och Folk **48**:1-471.
13. Kauffman, C. H., 1918. The Agaricaceae of Michigan. Lansing.
14. Maire, M. René, 1910. Notes critiques sur quelques champignons récoltés pendant la session de Dijon de la Société Mycologique de France. Bull. de la Société Mycologique de France **26**:159-198.
15. Moffatt, W. S., 1909. The higher fungi of the Chicago Region. Chicago Acad. Sci. Bull. **7**(1).
16. Peck, Charles H., 1888. Report of the state botanist. N. Y. Mus. Rept. **41**:51-122.
17. Quélet, M. L., 1872. Les champignons du Jura et des Vosges. (Supplements cover the period 1873-1890.)
18. Quélet, M. L., 1888. Flore mycologique de la France.

[1]This fungus best fitted the description of *Russula atropurpurea* Maire (ex. Kromb. non Peck) as given by Kauffman, but the writer was unable to determine the correct author citation. Dr. Gertrude S. Burlingham has informed the writer that Krombholz described a species in 1845 to which he gave the name *Agaricus (Russula) atropurpureus.* This was transferred to the genus *Russula* by Maire in 1910 as "*Russula atropurpurea Kromb.* Abb. d. Pilze **9**:6, t. 74, f. 5-6; non Peck!" However, since Peck had already described an entirely distinct species in 1888 as *R. atropurpurea,* Maire's transfer of Krombholz's *A. atropurpureus* to the genus *Russula* cannot carry with it Krombholz's original specific name. It, therefore, seems quite likely that Krombholz's plant does not at present have a name. It is also possible, according to Dr. Burlingham, that Kauffman's *R. atropurpurea* is not Krombholz's plant but some other species. Because of these facts, it seemed better to refer to the fungus merely as *R.* sp.

# Some Studies of the Genus Elymus

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The genus Elymus, commonly known as the rye grasses, includes many species in the northern hemisphere. Deam, in *Grasses of Indiana*, states that 25 species are found in the United States, chiefly in the western states.

The present study is not a taxonomic one but is directed rather towards the habits, reproduction, and chemical nature of the plant with a view to its possible economic value and modification in the direction of greater usefulness to man.

*Elymus virginicus* L. first came under observation in October, 1937. The original source of materials was a group of plants growing along the roadside in the Ohio river bottoms of Vanderburgh County, Indiana. This is a location frequently inundated at flood time. In November, 1937, *Elymus virginicus* var. *jejunus* (Ramaley) Bush. was collected on the top of Pilot Mountain near Ironton, Missouri, in the Ozark region.

Observation of these species shows that they are perennial. The new growth each year comes from buds at the lower nodes, which are frequently below the surface of the ground. Several new shoots develop from the base of each old culm so that the cluster tends to increase in size annually. One seed of variety *jejunus* germinated in the laboratory in February, 1938, produced a cluster of short culms in 1938 but produced no spikes. In 1939 the same plant with garden cultivation produced 147 fully developed spikes. The species observed will thus maintain themselves, tending to occupy the area more fully each year. These species do not produce rhizomes and show no tendencies which might make them objectionable because of being difficult to destroy, as is the case with some grasses such as the well-known quack grass.

Elymus matures slowly; it does not ripen in the sense that wheat does. In 1939 plants were in full bloom July 5; the spikes were harvested September 16. At this time some green still existed in leaves and culms, and some glumes were green. This occurred in a very dry season. In nature, seeds begin to fall from the plant about November 1 and continue to fall through most of the winter. Seeds lying on the ground were found germinating in February and by March were rooted. Experiments to determine most satisfactory planting time have not yet been completed.

The seed of the rye grasses is elongated in form, similar to those of the cultivated rye. It is usually dark in color. The lemma and palea are partially adherent to the seed and are removed with difficulty. Any threshing operation yields a product very similar in appearance to the cultivated oat.

A chemical analysis of the seeds of variety *jejunus*, after lemma and palea have been removed, gives the following protein content:

1938 crop ..... 27.20% protein
1939 crop ..... 27.22% protein

On the same basis of analysis other cultivated grain yields the following protein content:

| | Mean | Range | |
|---|---|---|---|
| Rye[2] | 12.4% | 8.4% | 19.% |
| Wheat[1] | 12.2% | 8.5% | 17.% |
| Barley[2] | 11.5% | ..... | ..... |
| Oats[2] | 12.1% | 9.1% | 15.% |
| Corn[1] | 10. % | ..... | ..... |
| Elymus[3] | 27.2% | ..... | ..... |

In this analysis the total nitrogen in the sample is determined, and this figure, multiplied by a predetermined factor for cultivated rye, was used, since none is on record for Elymus. For this reason, it is probably preferable to compare the nitrogen findings for the grain.

Nitrogen content of cultivated grasses is as follows:

| | |
|---|---|
| Rye[2] | 1.98% |
| Wheat[1] | 2.14% |
| Barley[2] | 1.84% |
| Oats[2] | 1.93% |
| Corn[1] | 1.60% |
| Elymus[3] | 4.845% |

If Elymus is to have any economic value to man, the size of the seed is of great importance. Considerable variation has been noted. Twenty-seven seeds of *Elymus virginicus* were carefully weighed after removal of lemma and palea; these averaged .00263 gm. When the variety *jejunus* was found, its seed proved to be much larger. Fourteen seeds, weighed under identical conditions, averaged .00407 gm. This represents an increase of 54.7% over the earlier varieties studied.

In the spike of Elymus spikelets are borne in pairs lying close together. Glumes are long, narrow, and indurated. The spikelet contains two or three florets. One or two may mature, but the third seldom contains a seed. The spikelets may disarticulate either above or below the glumes in about equal numbers. Those florets that disarticulate from the glumes may be separated out quite well by sifting and fanning methods. Those which remain attached to the glumes are separated with great difficulty.

General observations indicate that Elymus is very drought resistant. Along the roadside in Kansas in August, 1939, it was quite well-developed although cultivated wheat had been almost a total failure and the corn crop had been destroyed by drought and hot winds.

In its present wild condition the grain of Elymus would scarcely be useful to man except in stock feed because of the adherent lemma and

[1]Sherman, H. C., 1924. Food products. New York.

[2]David, W. A., and S. S. Sadler, 1917. Allen's commercial organic analysis. Philadelphia.

[3]Done by Department of Chemistry, Evansville College.

palea. If varieties with larger grain which can be separated from adhering coverings can be found or developed, it may find important uses.

Numerous new collections were made in August, 1939, in the states of Nebraska, Wyoming, Colorado, Kansas, and Missouri. These undoubtedly include several varieties. Hybridization has not yet been tried.

# Notes on Some Indiana Plants

R. M. Tryon, Jr., Gray Herbarium, Cambridge, Massachusetts

***Pteridium aquilinum* (L.) Kuhn var. *pseudocaudatum* (Clute) Heller.**—Peattie in his Flora of the Indiana Dunes lists *Pteridium latiusculum* var. *pseudocaudatum* as "sometimes found with the species in our area, acc. to Clute." This report is not known to be substantiated by a specimen, and, since numerous collectors have failed to find var. *pseudocaudatum* in the Dunes, it seems best to disregard it until authentic material is found.

However, on the Taxonomists' Field Trip this summer, characteristic specimens were collected on a sand hill along the C. & E. I. R. R., ½ mile south of Emison, Knox Co. (Tryon 4268). Also, there is a specimen in the herbarium of Mr. C. C. Deam collected in 1913 in a wooded ravine 1 mile east of Taswell, Crawford Co. (Deam 13976). The ultimate segments are long, entire, and glabrous or glabrate. These are the northernmost stations in the Mississippi Valley. Besides its broad Coastal Plain range from Long Island, New York, to Texas, it occurs throughout the southern half of Missouri, and I have seen one specimen from Kentucky.

***Convolvulus spithamaeus* and *C. sepium*.**—Following the author's recent treatment in Rhodora 41:415 (1939), the specimens of these two species in the herbarium of Mr. C. C. Deam have been identified as follows:

The descriptions have been drawn up from the Indiana material.

*C. spithamaeus* L. (typical)—Plant somewhat pubescent to glabrate, erect, short and compact, or sometimes tall, but the tip not prolonged; leaves tapering, rounded, auricled or sagittate at the base; basal leaves not more than one-half as long as some of the upper ones, often much reduced; petiole of the first leaf above the uppermost flower usually not more than one-fourth as long as the blade, rarely one-third as long; flowers white, usually 1-2, rarely 3-4.

Southwestern Quebec to Ontario and Minnesota, south to Iowa, Illinois, Kentucky, Pennsylvania, and Maryland, and in the mountains to West Virginia and Virginia.

Indiana: Clark, Dearborn, Harrison, Lawrence, Noble, Porter, Steuben, Tippecanoe, Wells, and Whitley counties.

*C. spithamaeus* L. var. *Catesbeianus* (Pursh) Tryon—Plant fairly pubescent, tall, the tip prolonged; leaves sagittate; basal leaves small as in typical *spithamaeus;* petiole of the first leaf above the uppermost flower at least one-third as long as the blade; flowers white, 1-7.

Virginia to Georgia and Alabama; Indiana.

Indiana: Crawford, Noble, Orange, Perry, and Pike counties.

The Indiana material is typical except that two specimens (Deam 24928, 7 flowers, Deam 35606, 6 flowers) have more flowers than I have seen before in this variety. However, typical *C. spithamaeus* may rarely

have as many as ten flowers (Greenbriar Co., West Virginia, Hunnewell 6701, Herb. Hunnewell), and so it may be expected that var. *Catesbeianus* would be equally variable in this character. Nevertheless, the specimens with many flowers look very much like *C. sepium* var. *repens* and can be referred here only because of their small basal leaves and the typical "spithamaeus" leaf-shape, which is very difficult to actually describe.

This is the first report for the state.

*C. sepium* L. var. *communis* Tryon—Plant essentially glabrous; leaves hastate, the basal lobes angled; flowers pink; peduncles usually exceeding the petioles but rarely the leaves.

Southern Quebec south to Virginia and sparingly to Florida, west to Minnesota, Oregon, and Washington.

INDIANA: Lake, Ripley, Vigo, and Whitley counties. A doubtful specimen from Allen county.

This is the first report for the state.

*C. sepium* L. var. *americanus* Sims—Plant essentially glabrous; leaves sagittate, the basal lobes rounded or slightly pointed; flowers pink; peduncles often exceeding the leaves.

Newfoundland, southern Quebec and Nova Scotia, south along the coast to Maryland and Virginia; also about the Great Lakes in Ontario, Ohio, Michigan, Indiana, Wisconsin, and Minnesota.

INDIANA: Lagrange, Laporte, Kosciusko, and Steuben counties. A doubtful specimen from Miami county.

First report for the state in Rhodora 41:415 (1939).

*C. sepium* L. var. *repens* (L.) Gray—Plant pubescent to essentially glabrous; leaves sagittate or sometimes hastate, the basal lobes usually rounded, sometimes the leaf sagittate and the lobes angled, leaf-blade characteristically long and narrow; flowers white or white with a pink margin; peduncles not exceeding the leaves.

Rhode Island to Florida, Louisiana and Missouri on the Coastal Plain; in the mountains of West Virginia; scattered in Indiana, not confined to the areas in which typical Coastal Plain plants are usually found.

INDIANA: Bartholomew, Brown, Carroll, Clay, Dearborn, Greene, Hamilton, Hancock, Harrison, Hendricks, Montgomery, Perry, Putnam, Shelby, Spencer, Tipton, Vermillion, Wells, and White counties.

Although the specimens in the Gray Herbarium indicate that var. *repens* has a typical Coastal Plain range, its distribution in Indiana is not that of a typical Coastal Plain plant.

*C. sepium* L. var. *fraterniflorus* (Mack. & Bush) Mack. & Bush—Plant pubescent to essentially glabrous; leaves hastate, the basal lobes angled; flowers white; peduncles usually exceeding the petioles but rarely the leaves.

Indiana to Montana, south to Arkansas and New Mexico.

INDIANA: Adams, Allen, Floyd, Greene, Knox, Owen, Posey, Warrick and Wells counties. A doubtful specimen from Benton county.

# A Titrimetric Method for the Determination of Nicotine in Tobacco Tissues

RAY F. DAWSON, DePauw University

A great many accurate and valuable methods have been developed for the quantitative estimation of nicotine in samples of tobacco tissue. The procedure most generally employed is that recommended by the Association of Official Agricultural Chemists in which nicotine is precipitated as the silicotungstate from a steam distillate of the tobacco tissues. This method is time-consuming, however, and requires careful temperature control during the ashing process. A new method has been devised which permits the rapid separation of nicotine from the remainder of the volatile bases which pass over with nicotine during the steam distillation. In its principal features, this method combines the steam distillation portion of the official method[1] with the ammonia distillation procedure described by Vickery and his associates.[2]

At ordinary pressures nicotine passes quantitatively into the vapor phase when steam is passed through its aqueous solution. In this state it is generally associated with ammonia and with small amounts of unknown bases. The vapor phase, when passed into standard acid, loses its basic constituents which, consequently, may be determined by direct titration with alkali. Since nicotine is nearly as strong a base as sodium hydroxide, it titrates quite readily. Under reduced pressure and at the boiling point of water, ammonia and the remainder of the lower boiling bases pass from the aqueous phase into the vapor phase; nicotine remains behind. The former may be trapped in standard acid and again titrated. The nicotine equivalent of the difference between the two titrations may then be calculated. If a positive determination is desired, the nicotine may be redistilled from the residues and titrated directly.

The advantages of the method are the rapidity with which individual analyses may be completed and its ease of application to semi-micro procedures. If suitable apparatus is available, duplicate determinations may be completed parallel with one another in a period of one hour or less. Furthermore, samples of tissue weighing 0.20 gm. may be employed, provided the volume of the distillation system is sufficiently small. Duplicate determinations usually check within 3% or less of one another. Very frequently the agreement is exact. Repeated tests have shown that, under the conditions prescribed for the conduction of the vacuum distillation, nicotine is not volatilized in sufficient amounts to be detected by qualitative reagents such as silicotungstic and picric acids even when the distillate is concentrated to a small volume. When compared with the usual silicotungstic acid quantitative method, the

[1]Official and tentative methods of analysis of the association of official agricultural chemists, 1935. Fourth ed. P. 60.

[2]Pucher, G. W., H. B. Vickery, and C. S. Leavenworth, 1935. *Ind. Eng. Chem., Anal. Ed.* 7:152.

new procedure gives results which are in reasonable agreement. In Table I are listed the results of a few repetitive and comparative analyses in which the new method has been employed.

TABLE I.—Percentage of Nicotine in Dry Tobacco Samples by Titrimetric Method and by Gravimetric Method

| Sample | Titrimetric Method | Gravimetric Method |
|---|---|---|
| | Percentage | Percentage |
| 1 | 9.57 | |
| | 9.49 | |
| 2 | 3.96 | |
| | 3.94 | |
| 3 | 0.90 | |
| | 0.90 | |
| 4 | 0.24 | |
| | 0.25 | |
| 5 | 9.50 | 9.72 |
| 6 | 5.85 | 5.98 |
| 7 | 0.63 | 0.65 |
| 8 | 0.42 | 0.40 |

Since the new method represents merely the combination of two procedures which have been described very thoroughly elsewhere in the literature[1,2], a brief outline of its adaptation to semi-micro analysis will be included here.

### The Titrimetric Method

The sample of dry, finely powdered tissue is well mixed, and 0.20 gm. of the powder is transferred from a weighing bottle to a 125 cc. Erlenmeyer flask and suspended in 20 cc. of water. If an aqueous extract of tobacco tissues is employed, the aliquot to be used for analysis should contain not less than 0.5 mgm. of nicotine. Three drops of paraffin oil and 0.2 cc. of a concentrated nitrogen free solution of sodium hydroxide are added, and the flask is attached to a steam distillation apparatus. The receiver should be charged with an appropriate volume of 0.0200 *N* HCl delivered from a micro burette which is calibrated in units of 0.02 cc. Distillation is continued with bottom heat until about 50-75 cc. of distillate are collected, depending upon the nicotine content of the tissues. Titration to the end-point of a methyl red-methylene blue indicator yields the total volatile base content of the tissues.

The distillate is then quantitatively transferred to a 200 cc. round bottom flask, and a few drops of a sodium hydroxide-sodium borate solution (5 gm. of borax dissolved in 100 cc. of 0.5 *N* nitrogen free sodium hydroxide)[2] are added. Standard acid is placed in the suction flask-

receiver, and the vacuum pump is turned on while the nicotine solution is still at room temperature. When the solution begins to discharge its dissolved gases vigorously, a water bath previously warmed to 42°C. is raised around the flask and distillation continued for 20 minutes. At the end of this time, the water bath is lowered, the vacuum released very slowly, the suction flask removed from the apparatus, and the distillate titrated as before. The difference between the two titrations corrected for the apparatus blank (usually between 0.02 and 0.04 cc. of 0.0200 *N* acid) and multiplied by the nicotine equivalent of the standard acid yields the quantity of nicotine contained in the sample of tissue.

The author is indebted to the National Research Council for financial assistance and to Professor S. F. Trelease of the Department of Botany of Columbia University and Dr. H. B. Vickery of the Connecticut Agricultural Experiment Station for generous contributions of their time and laboratory facilities in the completion of this and related researches.

# CHEMISTRY

Chairman: H. T. Briscoe, Indiana University

The address of Chairman H. T. Briscoe on Two Decades in the History of Chemistry and the paper on The Preparation of Acetyl Bromide, by M. T. Bruton and Ed. F. Degering, are published by title only.

Karl Means, Butler University, was elected chairman for 1940.

## The Adsorption of Potassium Ferrocyanide and Ferric Sulfate by Prussian Blue

E. W. Kanning and A. W. Campbell, Indiana University

Studies concerning the composition of Prussian blue precipitates formed by the interaction of the ferric and ferrocyanide ions have led to interesting and, in some instances, conflicting conclusions. It has been shown that, when the reactants are mixed, oxidation-reduction reactions and adsorption occur which prevent the formation of the stoichiometric compound, $Fe_4[Fe(CN)_6]_3$. Bhattacharya and Dhar[1] report experiments that indicate that this compound is formed when a solution of ferric chloride is added to a solution of potassium ferrocyanide. They further point out that, when the precipitate is allowed to age in contact with the supernatant liquid, the composition of the precipitate changes to approach an equilibrium mixture as a result of either oxidation-reduction or adsorption processes or both. It is pointed out that Prussian blue is primarily susceptible to adsorption processes.

The simple compound, $Fe_4[Fe(CN)_6]_3$, is formed, according to Müller,[2] only if the solutions of ferric iron and ferrocyanide are of definite concentrations. In most cases the percipitate consists of a complex mixture, the exact composition of which depends upon the conditions under which it is prepared. Woringer[3] states that commercial iron blue is a complex compound, $Fe''' Fe''_3[Fe_3(CN)_6]_3$, which is formed as the result of the mutual oxidation and reduction of the ferric and ferrocyanide ions. Schmidt and Rassow[4] are of the opinion that Prussian blue is a ferric ferrocyanide in which part of the iron is replaced by potassium and two molecules of water in intermolecular combination. Davidson and Welo[5] state that the formulas for the "soluble" and "insoluble" blues are $KFe[Fe(Cn)_6]$ and $Fe_4[Fe(CN)_6]_3$, respectively. Justin-Mueller[6] suggests the formula, $Fe'''[Fe''' \vdots (CN)_6 : Fe'']_3$

[1]Bhattacharya, A., and Dhar, N. R., *Z. für anorg, und allgem. Chem.*, **213**:240-8 (1933).

[2]Müller, E., *Journ. prakt. Chem.*, 84:353-69 (1911).

[3]Woringer, P., *Chem.-Ztg.*, **36**:78 (1912).

[4]Schmidt, P. F., and Rassow, B., *Z. Angew. Chem.*, **37**:333-4 (1924).

[5]Davidson, D., and Welo, L. A., *Journ. Phys. Chem.*, **32**:1285-9 (1931).

[6]Justin-Mueller, E., *Bull. Soc. Chim.*, **49**:1285-9 (1931).

From experiments carried out by Ihne and Kanning[7] concerning the composition of iron blue, it was concluded that Prussian blue prepared by the oxidation of the so-called "white paste" (primarily ferrous ferrocyanide with adsorbed alkali ferrocyanide) consists of ferric ferrocyanide in combination with the alkali ferrocyanide as an adsorption product. The extent of the adsorption of the soluble ferrocyanide was found to depend upon the relative concentrations and proportions of the ferrous and ferrocyanide ions used in the preparation of the ferrous ferrocyanide.

The experiments reported in this paper are for the purpose of determining quantitatively the adsorptive capacity of Prussian blue for potassium ferrocyanide and ferric chloride in an effort to add to the already existing data concerning the fact that Prussian blue, when prepared, contains contaminating substances as adsorption products. The adsorption experiments were performed on Prussian blue precipitates, prepared and dried in a specific manner. The effect of ageing the prepared precipitate was also studied.

## Experimental

**Preparation of the Prussian blue precipitates.**—The Prussian blue was prepared by adding 2,625 ml. of 2N ferric sulfate solution to 2,500 ml. of 2N potassium ferrocyanide solution. The mixture was stirred thoroughly and divided into two equal parts.

One part of the mixture was filtered with suction, washed free of soluble ions and dried at a temperature of 95°C. for 50 hours. The dried Prussian blue was then pulverized and again dried for 95 hours at 95°C. This product was ground in an agate mortar until it passed a 100 mesh sieve and is designated "fresh" Prussian blue.

The second portion of the precipitated Prussian blue was transferred to a large flask and maintained at a temperature of 98°C. for 240 hours. After this "ageing" process, the precipitate was filtered, washed, dried, and pulverized in the same manner as was the first portion. This particular sample was designated "aged" Prussian blue.

**Determination of adsorptive capacities of the Prussian blues.**—The capacity of each of the two Prussian blues for adsorbing potassium ferrocyanide and ferric sulfate was determined at varying concentrations of the adsorbate. The procedure employed for the adsorption determinations was the same in each instance.

A sample of the powdered Prussian blue, weighing 10.000 gm. was placed in 100 ml. of the solution of the adsorbate contained in a 125 ml. Erlenmeyer flask which had previously been immersed in a constant temperature bath at 25°C. The flask was then stoppered, shaken vigorously, and replaced in the constant temperature bath for 30 minutes. During this time, the contents of the flask were thoroughly mixed by shaking every five minutes. As is customary, adsorption equilibrium was assumed to be attained after 30 minutes.

When adsorption was complete, the contents of the flask were passed through a parlodion ultrafilter which served to separate well

[7]Ihne, R. E., and Kanning, E. W., *Ind. Eng. Chem.*, 31:88-9 (1939).

the Prussian blue from the solution of the adsorbate. The concentration of the filtrate from the ultrafiltration process was then determined which, when subtracted from the concentration before adsorption, yielded data from which the extent of the adsorption was calculated. Both the ferric and ferrocyanide ions were determined by titration in acid solution with potassium permanganate.

In order to avoid errors due to the dilution of the filtrate by water retained by the ultrafilter in its preparation or to the adsorption of ferric or ferrocyanide ions by the ultrafilter material, blank determinations were carried out. It was found that no change in concentration of the adsorbate solutions occurred when passed through the ultrafilter. It was also found by actual test that no detectable quantity of Prussian blue would pass the ultrafilter.

## Data and Results

The results obtained for the adsorption of potassium ferrocyanide by the "fresh" Prussian blue are presented in Table I. The extent of adsorption is represented by the values of X/M and is expressed as milli-equivalents of potassium ferrocyanide adsorbed per gram of Prussian blue. The table also includes the logarithms of the factors, C, and X/M, where C is the final concentration of adsorbate. The data in Table II shows the adsorption of ferric sulfate by the "fresh" Prussian blue. The curves in Fig. 1 are the graphical representations of the adsorption of potassium ferrocyanide (curve I) and ferric sulfate (curve II) by the "fresh" Prussian blue. The curves are obtained by plotting the values of X/M as ordinates and the final adsorbate concentration, C, as abscissae. The logarithm curves, obtained by plotting log. C and log. X/M are presented in Fig. 3, in which curve I represents the adsorption of the ferrocyanide and curve II the adsorption of ferric sulfate.

The results obtained for the adsorption of potassium ferrocyanide and ferric sulfate by the "aged" Prussian blue are presented in Tables III and IV, respectively. The adsorption curves for the "aged" sample

TABLE I.—Adsorption of Potassium Ferrocyanide by "Fresh" Prussian Blue

| Initial Conc. of $K_4Fe(CN)_6$ (g.eq./1) | Final Conc. of $K_4Fe(CN)_6$ (g.eq./1) (C) | Log C | X/M | Log X/M |
|---|---|---|---|---|
| 3.020 | 2.300 | 0.362 | 7.20 | 0.847 |
| 1.924 | 1.302 | 0.115 | 6.22 | 0.793 |
| 1.000 | 0.517 | −0.287 | 4.83 | 0.684 |
| 0.500 | 0.117 | −0.937 | 3.83 | 0.583 |
| 0.252 | 0.010 | −2.000 | 2.42 | 0.384 |
| 0.1124 | 0.0012 | −2.921 | 1.21 | 0.083 |
| 0.0504 | 0.0016 | −2.796 | 0.488 | −0.312 |

TABLE II.—Adsorption of Ferric Sulfate by "Fresh" Prussian Blue

| Initial Conc. of $Fe_2(SO_4)_3$ (g.eq./1 | Final Conc. of $Fe_2(SO_4)_3$ (g.eq./1) (C) | Log C | X/M | Log X/M |
|---|---|---|---|---|
| 2.76 | 2.663 | 0.0425 | 0.975 | −0.011 |
| 1.93 | 1.863 | 0.270 | 0.705 | −0.152 |
| 1.0125 | 0.969 | −0.014 | 0.435 | −0.362 |
| 1.011 | 0.960 | −0.018 | 0.510 | −0.292 |
| 0.5055 | 0.485 | −0.315 | 0.210 | −0.678 |
| 0.249 | 0.237 | −0.625 | 0.120 | −0.921 |
| 0.1134 | 0.1014 | −0.994 | 0.120 | −0.921 |
| 0.0564 | 0.0444 | −1.353 | 0.120 | −0.921 |

TABLE III.—Adsorption of Potassium Ferrocyanide by "Aged" Prussian Blue

| Initial Conc. of $K_4Fe(CN)_6$ (g.eq./1) | Final Conc. of $K_4Fe(CN)_6$ (g.eq./1) (C) | Log C | X/M | Log X/M |
|---|---|---|---|---|
| 2.637 | 1.940 | 0.288 | 6.97 | 0.843 |
| 1.918 | 1.385 | 0.141 | 5.33 | 0.727 |
| 1.449 | 0.959 | −0.018 | 4.90 | 0.690 |
| 0.999 | 0.639 | −0.195 | 3.60 | 0.556 |
| 0.498 | 0.259 | −0.587 | 2.39 | 0.378 |
| 0.260 | 0.1108 | −0.955 | 1.50 | 0.176 |
| 0.0493 | 0.00012 | −3.921 | 0.49 | −0.310 |

of Prussian blue are shown in Fig. 2; curve III represents the adsorption of potassium ferrocyanide and curve IV the adsorption of ferric sulfate. The log curves for the adsorption experiments with the "aged" Prussian blue are shown in Fig. 3; curve III represents the log C-log X/M relation for potassium ferrocyanide and curve IV the corresponding relation for ferric sulfate.

## Discussion of Results

From the data presented, it is apparent that positive adsorption from solution has occurred in all experiments. Both the "fresh" and the "aged" samples of Prussian blue possess a much greater adsorptive capacity for potassium ferrocyanide than for ferric sulfate. In Table I it is seen that, at an initial adsorbate concentration of 3.020 equivalents per liter, 1 gram of the adsorbent adsorbs 7.2 milli-equivalents or

TABLE IV.—Adsorption of Ferric Sulfate by "Aged" Prussian Blue

| Initial Conc. of $Fe_2(SO_4)_3$ (g.eq./1) | Final Conc. of $Fe_2(SO_4)_3$ (g.eq./1) (C) | Log C | X/M | Log X/M |
|---|---|---|---|---|
| 2.910 | 2.843 | 0.454 | 0.67 | −0.174 |
| 2.433 | 2.375 | 0.375 | 0.60 | −0.222 |
| 1.922 | 1.881 | 0.274 | 0.41 | −0.387 |
| 1.415 | 1.382 | 0.141 | 0.33 | −0.481 |
| 0.963 | 0.939 | −0.027 | 0.24 | −0.720 |
| 0.506 | 0.493 | −0.307 | 0.13 | −0.886 |
| 0.225 | 0.212 | −0.674 | 0.13 | −0.886 |

0.66 gm. of potassium ferrocyanide. The adsorption of ferric sulfate by the "fresh" Prussian blue was very slight, the maximum value of X/M being 0.975 milli-equivalents per gram of the adsorbent.

The adsorptive capacity of the "aged" sample of Prussian blue for the two salts studied was in general less at the same concentrations of adsorbate than that for the "fresh" sample. This difference in the adsorptive capacities of the two samples of the adsorbent can be seen by a comparison of curves I and II in Fig. 1 and curves III and IV in Fig. 2. The adsorptive capacity of the two samples of the Prussian blue for ferric sulfate is only slight; however, the adsorption of this salt by the "aged" adsorbent is slightly greater than that by the "fresh" sample. The data for the adsorption of ferric sulfate is considered subject to slight error because of the extremely small differences between the initial and final adsorbate concentrations.

Two explanations might serve to explain the effect of "ageing" the Prussian blue on its adsorptive capacity. The decreased capacity as a result of "ageing" at an elevated temperature could be due to a change in the physical nature of the adsorbent. The "ageing" process no doubt causes a general increased particle size, resulting in a decreased adsorbent surface. The effect of the "ageing" process by the formation, during the digestion period, of an equilibrium mixture of Prussian and Turnbull's blue has been suggested by experiments conducted by Bhattacharya and Dhar.[1] Turnbull's blue in general possesses less adsorptive capacity for the ferrocyanides, which would account for the effect of "ageing" of the precipitate studied. It is of interest to note (see curves I and II, Fig. 3) that the adsorptive capacity of the "fresh" Prussian blue exceeds that of the "aged" sample up to a potassium ferrocyanide concentration of about 2.0 N, beyond which the "aged" sample possesses the greater adsorptive capacity for this salt. It is difficult to explain this discrepancy.

The fact that adsorption has actually occurred in these experiments, especially in those involving the adsorption of potassium ferrocyanide, is evidenced by the nature of the curves that are obtained when the

concentration of the adsorbate is plotted against the quantity of adsorbate removed from solution. According to the adsorption equation, a parabolic curve should be obtained which yields a straight line when the logarithms of the coordinate factors are plotted. The curves in Figs. 1, 2, and 3 indicate that a process of adsorption is concerned in the removal of potassium ferrocyanide and ferric sulfate from solution by the two Prussian blues.

## Summary

From the experiments performed, data are obtained that indicate a large adsorptive capacity of precipitated Prussian blue for potassium ferrocyanide and a comparatively small adsorptive capacity for ferric sulfate.

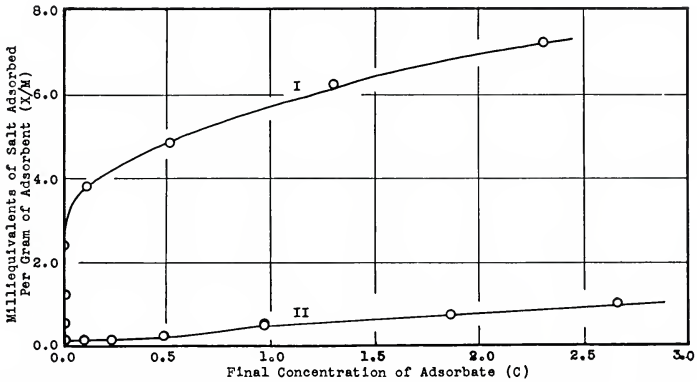


Fig. 1. Adsorption of potassium ferrocyanide and ferric sulfate by "fresh" Prussian blue. Curve I. Adsorption of potassium ferrocyanide. Curve II. Adsorption of ferric sulfate.

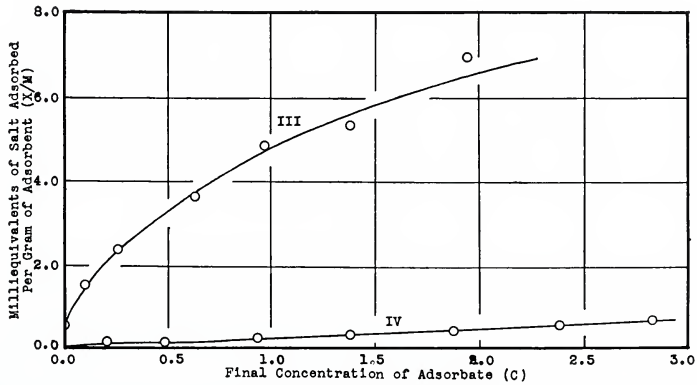


Fig. 2. Adsorption of potassium ferrocyanide and ferric sulfate by "aged" Prussian blue. Curve III. Adsorption of potassium ferrocyanide. Curve IV. Adsorption of ferric sulfate.

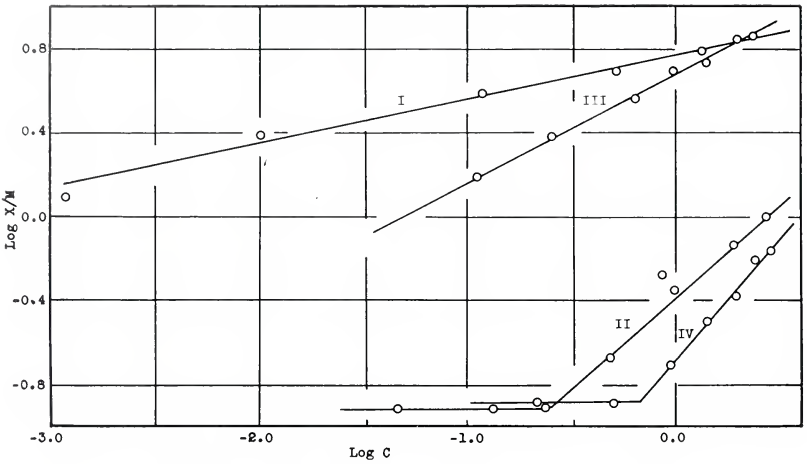


Fig. 3. Log X/M-log C relationship for the adsorption of potassium ferrocyanide and ferric sulfate by Prussian blue. Curves I and II. Adsorption of potassium ferrocyanide and ferric sulfate. Respectively by the "fresh" Prussian blue. Curves III and IV. Adsorption of potassium ferrocyanide and ferric sulfate. Respectively by the "aged" Prussian blue.

"Ageing" the precipitated Prussian blue for 240 hours at 98°C. produced an adsorbent which possessed a lesser adsorptive capacity for both potassium ferrocyanide and ferric sulfate.

The fact that the X/M-C curves follow the general form of the Freundlich adsorption isotherm is evidence that a true process of adsorption occurs in the removal of the two salts (potassium ferrocyanide and ferric sulfate) from solution by contact with dried Prussian blue.

The data presented in this and other papers seem to indicate that the explanation of the composition of precipitated Prussian blue should include the possible existence of the rather large quantities of soluble ferrocyanides and also small quantities of ferric salts adsorbed by the primary precipitate. Although the deviation of the composition of Prussian blue from the basic compound, $Fe_4[Fe(CN)_6]_3$, may not be accounted for entirely on the basis of the adsorption of soluble salts by the primary precipitate, the process of adsorption seems to play a very important part in the definition of the composition of the product obtained from the interaction of ferrocyanide and ferric ions.

# The Preparation of Amino Alcohols

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## Introduction

Since amino alcohols and their derivatives are of considerable importance as local anesthetics, their preparation has been the object of much attention. Three more or less general methods of preparation, as well as a host of minor ones, have been developed. In the first of these[1] the amino group is introduced into an ester, aldehyde, or ketone, and this amino compound is converted into an amino alcohol either by reduction or through the Grignard reaction. This method is very satisfactory in those cases where the amino alcohol can be readily isolated from aqueous solution and where the amino ester, aldehyde, or ketone is easily obtained and is stable. In the second method, which applies only to beta amino alcohols, the corresponding ethylene oxide is treated with ammonia or an amine.[2] This method is an excellent one but is limited by the availability of the ethylene oxides.

The third and most generally used reaction consists in treating the corresponding chloro (or bromo) hydrine with the desired amine, either at atmospheric pressure or in a sealed vessel, depending on the volatility of the reactants.[3] Ammonia does not work as well as primary and secondary amines. Since hydrogen halide is formed in the reaction, it is necessary to remove it for the reaction to proceed.

$$(CH_3)_2C(OH)-CH_2Cl + 2\,R_2NH \longrightarrow (CH_3)_2C(OH)-CH_2NR_2 + [R_2NH_2^+]Cl^-$$

Ordinarily, a second equivalent of amine is used for this purpose. This procedure has two main disadvantages. The yield of amino alcohol is apt to be low, especially in the case of the less basic, aromatic amines, and the procedure is an expensive one, particularly where the amine used is one of the higher, less readily available ones.

Since large amounts of amino alcohols were needed for work being conducted in this laboratory, a study was undertaken to determine whether inorganic bases could be substituted for the second equivalent of amine and, if so, to ascertain which inorganic bases were most suitable.[4]

## Experimental Procedure

**Reactions carried out at atmospheric pressure.**—One-fourth of a mole of the chlorohydrine, one-fourth of a mole of the amine, and a

[1]Mannich and Hof, 1927. *Arch. Pharm.* 265:589. Paal and Weidenkaff, 1906. Ber., 39:810.

[2]Krassusky, 1927. *Journ. prakt. Chem.* 115:322.

[3]Fourneau, 1904. *Compt. rend.* 138:766.

[4]The authors wish to thank Mr. Milton J. Eisert and Mr. William Long for doing part of the experimental work.

slight excess of the alkaline binding agent were mixed with the solvent. This usually consisted of 100 cc. of 50% alcohol, except in the cases where excess amine was used as binding agent, when the solvent was benzene. The mixture was heated under a reflux condenser for six to nine hours. It was then allowed to cool to room temperature and was poured into water. The organic layer was separated, the aqueous layer was made *strongly* basic with sodium hydroxide and extracted several times with ether. The combined ether extracts and the main organic layer were dried over anhydrous magnesium sulfate and then distilled through a Vigreux column or a modified Claisen flask, according to circumstances.

**Reactions carried out at higher pressures.**—One-fourth of a mole of the chlorohydrine, one-fourth of a mole of the amine, and a slight excess of the alkaline binding agent were dissolved or suspended in 150 cc. of dry benzene, and the mixture was heated in a small autoclave at 125-130°C. for eight to ten hours. The cooled mixture was filtered and the benzene solution was distilled.

## Discussion of Results

For the first phase of the study, the reaction of isobutylene chlorohydrine with the weakly basic ethylaniline was chosen. As can be seen from the data in Table I, no amino alcohol was obtained when excess amine was used as the binding agent. Pyridine and sodium acetate also proved to be too weakly basic to bring about a reaction.

TABLE I.—Reaction of Isobutylene Chlorohydrine and Ethylaniline at Atmospheric Pressure

| Binding Agent | Solvent | Yield of Amino Alcohol |
|---|---|---|
| Excess amine | Benzene | 0% |
| Pyridine | Benzene | 0% |
| Pyridine | Aqueous alcohol | 0% |
| Sodium bicarbonate | Aqueous alcohol | 48% |
| Sodium acetate | Aqueous alcohol | 0% |
| Boric oxide | Aqueous alcohol | 11% |
| Magnesium oxide | Aqueous alcohol | 28% |
| Calcium oxide | Aqueous alcohol | 36% |
| Potassium hydroxide | Aqueous alcohol | 26% |
| Trisodium phosphate | Aqueous alcohol | 15% |

Of the other binding agents tried, sodium bicarbonate was the most satisfactory, and the oxides of calcium and magnesium next. The relatively low yield of amino alcohol, obtained when potassium hydroxide was used, is probably due to the fact that it is too strong a base and caused partial decomposition of the tertiary chlorohydrine to the volatile isobutylene oxide, which escaped from the reaction mixture. From

the above data, it is permissible to conclude that, for a binding agent to be satisfactory, it must be a fairly strong base but that too strong a base causes side reactions which lower the yield of amino alcohol.

The use of sodium bicarbonate and sodium carbonate in the preparation of other amino alcohols from isobutylene chlorohydrine was investigated next. A good yield (47%) of amino alcohol was obtained from methylaniline, using sodium bicarbonate as binding agent and aqueous alcohol as solvent. Dibutylamine gave a 61% yield of the corresponding amino alcohol, and diethylamine a 46% yield. In extending the study to the higher, less basic aromatic amines, it was found that no amino alcohol could be obtained from isobutylene chlorohydrine and diphenylamine or alpha-naphthylamine, either in the presence or the absence of sodium carbonate. This is not especially strange since these amines are so weakly basic that they will not dissolve in dilute hydrochloric acid. For reasons as yet unexplained, dicyclohexylamine yielded no amino alcohol either with or without a binding agent.

Sodium carbonate and sodium bicarbonate proved to be satisfactory binding agents in the preparation of amino alcohols from trimethylene chlorohydrine and diethyl and dibutylamines. In this case also, dicyclohexylamine yielded no amino alcohol. These data are summarized in Table II.

TABLE II.—Preparation of Amino Alcohols from Chlorohydrines at Atmospheric Pressure

| Chlorohydrine | Amine | Binding Agent | Yield of Amino Alcohol |
|---|---|---|---|
| Isobutylene | Ethylaniline | $NaHCO_3$ | 48% |
| Isobutylene | Methylaniline | $NaHCO_3$ | 47% |
| Isobutylene | Di-n-butylamine | $Na_2CO_3$ | 61% |
| Isobutylene | Diethylamine | $NaHCO_3$ | 46% |
| Trimethylene | Di-n-butylamine | Excess amine | 33% |
| Trimethylene | Di-n-butylamine | $NaHCO_3$ | 48% |
| Trimethylene | Di-n-butylamine | $Na_2CO_3$ | 47% |
| Trimethylene | Diethylamine | $NaHCO_3$ | 53% |

Since, with the lower-boiling amines, it is desirable to carry the reaction out in a sealed vessel to avoid losses and since, obviously, sodium carbonate or bicarbonate cannot be used under such conditions, it seemed advisable to investigate the use of other binding agents for this purpose. From the data in Table I, it seemed that magnesium oxide would be suitable. This proved to be the case for the reaction of diethylamine with isobutylene chlorohydrine. Using excess amine as binding agent, a 19% yield of amino alcohol was obtained. Under the same conditions of time, temperature, solvent, and pressure but substituting magnesium oxide for the excess amine, the yield of the amino alcohol was increased to 30%.

The physical constants of the amino alcohols prepared in the course of this work are recorded in Table III. Not all of these have been described before.

TABLE III.—Physical Constants of Amino Alcohols

| Amino Alcohol | B.pt. °C. | Press. mm. | $n_D^{20}$ | $d_4^{20}$ |
|---|---|---|---|---|
| Methylanilino-tert-butyl alcohol | 132-133° | 12 | 1.5479 | 1.0160 |
| Ethylanilino-tert-butyl alcohol | 137-138° | 12 | 1.5418 | 1.0029 |
| Dibutylamino-tert-butyl alcohol | 118-119° | 21 | 1.4379 | 0.8422 |
| Diethylamino-tert-butyl alcohol | 78-80° | 45 | 1.4253 | 0.8382 |
| 3-Diethylamino-1-propanol | 85-86° | 20 | 1.4439 | 0.8600 |
| 3-Dibutylamino-1-propanol | 121-122° | 11 | 1.4476 | 0.8617 |

**Summary**

1. The use of alkaline, inorganic binding agents in the preparation of amino alcohols from chlorohydrines and secondary amines has been investigated.

2. Sodium carbonate and sodium bicarbonate have been shown to be the most satisfactory binding agents for reactions at atmospheric pressure. In many cases, the use of these substances increases the yield of amino alcohol markedly. Magnesium oxide appears to be a satisfactory binding agent for use at higher pressures.

# Enzymatic Action in the Presence of Some Common Antiseptics

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Many diversified studies of the influence of foreign materials on enzymatic action have been made. An attempt to compare the antiseptic properties of various compounds by yeast fermentation seems to have been made first by Dreser[1] in a study of colloidal silver preparations.

The effect of mercury compounds on yeast fermentation was studied in somewhat the same manner by Peterson[2]. As a result of his investigation, he was able to classify the mercurials, using mercuric chloride as a standard, into four groups depending upon their ability to inhibit the fermentative process. He concluded that the inhibitive effect of the yeast sugar fermentation, in most cases, is due to the mercuric ion concentration although, in some cases, other components of the solution were concerned.

By means of a simple device for quantitatively collecting the carbon dioxide produced by yeast fermentation, Branham[3] confirmed the principles of the yeast fermentation method of comparing antiseptics and also showed that the method had a general application.

The purpose of this investigation was three-fold: first, to study the influence of many common antiseptics on yeast sugar fermentation; second, to compare the effect of certain antiseptics on the enzymatic action of zymase with that of catalase, trypsin, and pepsin; and, third, to determine the influence of these antispetics on the action of the above enzymes in the presence of normal horse serum.

## Experimental

In Table I are listed the antiseptics used in this investigation, showing their trade or common name, their chemical name, and the manufacturer or distributor from whom the antiseptics were obtained. The enzymes studied were yeast zymase, yeast catalase, pepsin, and trypsin.

The acriflavine, merthiolate, metaphen, pepsin, pancreatin, trypsin maltase, and the normal horse serum were supplied through the courtesy of Eli Lilly and Company, Indianapolis, Indiana.

The general method of procedure was to determine the concentration or quantity of antiseptic required to completely impede the activity of each of the enzymes studied.

## Yeast Zymase

Ordinary cakes of Fleishmann's yeast were used in this work, and they were purchased every other day to assure fresh starting material. A 20% solution by weight of yeast was used throughout the study. This

[1]Dreser, 1917. Ztschr. f. Exper. Path. U. Therap. 19:285.
[2]Peterson, 1926. Journ. Amer. Med. Assoc. 87:223.
[3]Branham, 1929. Journ. Infect. Dis. 44:142.

TABLE I.—Antiseptics Used in This Investigation

| Trade or Common Name | Chemical Name | Manufacturer or Distributor (U.S.A.) |
|---|---|---|
| Alcohol | Ethyl Alcohol | Commercial Solvents Corp. |
| Acriflavine | 3.6 Diamino -10-Methylacridinium Chloride Monohydrochloride | Abbott Laboratories |
| Argyrol | | A. C. Barnes Co. |
| Boracic Acid | Boric Acid | Coleman and Bell |
| Blue Vitriol | Copper Sulfate | Coleman and Bell |
| Carbolic Acid | Phenol | Mallinckrodt Chemical Co. |
| Corrosive Sublimate | Mercuric Chloride | Coleman and Bell |
| Ferric Chloride | Ferric Chloride | Coleman and Bell |
| Glycotanphene | | Tannin Products, Inc. |
| Lavoris | | The Lavoris Co. |
| Listerine | | |
| Mercurochrome | Dibrom-Oxymercuri-Fluorescein | Hynson, Westcott and Dunning, Inc. |
| Merthiolate | Sodium Ethyl Mercurithiosalicylate | Eli Lilly and Co. |
| Metaphen | 4-Nitro-Anhydro Mercuri Ortho-Cresol | Abbott Laboratories |
| Neo-Silvol | | Parke Davis and Co. |
| Pepsodent | | The Pepsodent Co. |
| Potassium Permanganate | Potassium Permanganate | Coleman and Bell |
| Silver Nitrate | Silver Nitrate | Daigger Chemical Co. |
| S.T. 37 | Hexylresorcinol | Sharp and Dohme |
| Zinc Sulfate | Zinc Sulfate | Coleman and Bell |

solution was prepared by dissolving or suspending 40 gm. of the yeast in enough distilled water to make the final volume 200 ml. This yeast suspension was stored in a refrigerator at a temperature of approximately 5° C.

All weighing, accurate to the fourth decimal place, was done on an analytical balance, and all dilutions were made with a burette or pipette or both. All stock solutions were made by dissolving the antiseptic or enzyme in enough distilled water to give the desired concentration. For example, to make a so-called 1-100 solution, one gram of the antiseptic or enzyme was dissolved and diluted with enough distilled water to make the final volume of the solution 1,000 ml.

The test solutions were made up and mixed in the following order: 2 ml. of the desired antiseptic solution, 2 ml. of a 50% sugar solution, 6 ml. of distilled water or serum, 2 ml. of a 20% yeast suspension.

When those antiseptics which did not greatly retard enzymatic action were used, the ratio of the volume of water or serum to the volume of the antiseptic solution varied somewhat, but the total volume of antiseptic solution and water or serum was always maintained at 8 ml. The amount of sucrose solution and yeast suspension was never changed. The above portions were measured from freshly prepared solutions into test tubes by means of a 2 ml. pipette, thoroughly mixed, poured into saccharometer or fermentation tubes and incubated for two hours at a temperature of 38° C., plus or minus one degree.

TABLE II.—A Summary of the Data Obtained in the Study of Yeast Zymase

| Antiseptic | End Point in Aqueous Sol. (Concentration) | End Point in a 50% Serum (Concentration) |
|---|---|---|
| Alcohol | 15.8% (1-6.3) | 17.4% (1-5.7) |
| Acriflavine | 1-1200 | 1-400 |
| Argyrol | 1-15 | No inhibition |
| Boric Acid | No inhibition | No inhibition |
| Copper Sulfate | No inhibition | 1-180 |
| Carbolic Acid | 1-180 | 1-150 |
| Corrosive Sublimate | 1-18,000 | 1-6000 |
| Ferric Chloride | No inhibition | No inhibition |
| Glycontaphen | 1-1.7 | 1-1.5 |
| Lavoris | No inhibition | No inhibition |
| Listerine | 1-3 | 1-2.4 |
| Mercurochrome | 1-90 | 1-50 |
| Merthiolate | 1-240 | |
| Metaphen | 1-6000 | 1-4000 |
| Neo-Silvol | No inhibition | No inhibition |
| Pepsodent | 1-5 | 1-3 |
| Potassium Permanganate | No inhibition | No inhibition |
| Silver Nitrate | 1-18,000 | 1-120 |
| S.T. 37 | 1-3500 | 1-2400 |
| Zinc Sulfate | No inhibition | 1-20 |

**Discussion of data obtained with yeast zymase.**—In performing the experiments using alcohol as antiseptic, it was found that, when the final concentration of the alcohol was greater than about 16%, a protein precipitate formed as the serum was added to the alcohol mixture and the quantity of precipitate increased with increasing alcohol concentration. No precipitate was observed in those tubes containing only water.

In both aqueous and serum media, it was found that low concentrations of argyrol enhanced the activity of zymase. In a serum medium, some repression was noticed when the concentration of argyrol was increased to about 1-10. No precipitation was observed in either medium within the limits studied.

A discoloration due to a precipitate occurred in the mixture containing the stronger concentrations of acriflavine and metaphen when the yeast and serum were added. The fact that the yeast gave a decidedly heavier precipitate might be due to the acid characteristics of the yeast.

In aqueous solution, boric acid repressed the yeast sugar fermentation but did not completely inhibit it. Apparently the retardation was proportional to the amount of acid added. In serum medium, however, the reaction started in the fermentation tubes containing boric acid before it did in those tubes containing the acid and those not containing it. In the more dilute solution, 1-100, the boric acid apparently increased the activity; in the tubes containing higher boric acid content, retardation occurred although the reaction was not completely stopped.

It is of interest to note that minimum activity of yeast zymase appeared near a copper sulfate concentration of 1-2,000 although complete inhibition was not obtained. The amount of carbon dioxide evolved in-

creased gradually on both sides of this interval. When the serum was added, precipitation occurred near a concentration of 1-900 and continued through a maximum at a concentration of between 1-60 and 1-200. During the first few minutes the activity was greatest at a concentration of about 1-1,000.

The serum was precipitated by the carbolic acid when its final concentration was made more than 1% with respect to phenol. In all dilutions greater than the end point of the experiment (1-80 for aqueous solution and 1-150 for serum solution), the tubes containing serum reacted first and more rapidly than those which did not contain phenol.

Within the range of concentrations studied, mercuric chloride did not precipitate the proteins of the serum.

Ferric chloride did not completely stop yeast sugar fermentation although for concentrations greater than 1-15 in both aqueous and serum media very little carbon dioxide was given off. In aqueous solutions maximum activity occurred at a final concentration of approximately 1-100. The serum formed a jelly-like mass with the iron which was difficult to remove from the fermentation tubes when the final concentration exceeded 1-50.

There was a slight precipitation when the serum was added to the glycotanphene at a final concentration of 1-2.5. The precipitation increased as the concentration of the antiseptic increased.

Pepsodent and listerine slightly precipitated the serum in concentration from 1-2 or 1-3, but there was no noticeable increase in the precipitation as the concentration of the antiseptics increased.

A curdy, flocculent precipitate formed in all of the fermentation tubes containing mercurochrome with a separation of the precipitate from the more dilute solutions. At a concentration of 1-40 a jelly-like mass was formed. When the serum was added, the precipitation seemed to be more pronounced between the concentrations of 1-60 and 1-120. No precipitation was noted from a solution of a concentration of 1-40.

Neo-Silvol did not inhibit yeast sugar fermentation. All tubes containing the antiseptic, within the concentrations studied, were more active than those which did not contain it.

Experiments using potassium permanganate as antiseptic, with concentrations varying from 1-100 to 1-9,000 in rather small intervals of dilution, were repeated several times. The datum cited in Table II is representative of the whole. Several of the various sets of data showed that the end point in aqueous solution is near 1-1,800; other sets seemed to be more active, the greater the concentration of salt. After 30 minutes, there was approximately two times as much carbon dioxide in the fermentation tube containing a concentration of 1-500 than there was in those tubes containing no antiseptic. There was more or less precipitation of manganese dioxide, increasing with the concentration in all dilutions. When serum was added to the potassium permanganate, precipitation occurred. The extent of precipitation increased with the antiseptic concentration in all tubes having a concentration of salt greater than 1-600. Several trials were made using solutions having a final strength varying from 1-100 to 1-500, and it was found that the tubes containing the salt were more active than those which did not con-

tain it. After 45 minutes, the tube containing a concentration of 1-600 had approximately twice as much gas in it as those containing no potassium permanganate, and the activity seemed to increase with increasing salt concentration.

Silver nitrate began precipitating the proteins of the serum in a concentration of 1-15,000 with respect to the salt, and the amount of precipitation increased as the concentration of silver nitrate increased. The degree of inhibition was also proportional to the amount of salt present.

Zinc sulfate was studied from a concentration of 1-4 to 1-15,000 inclusive. As the concentration of salt increased, the activity also increased. Within the range of the concentrations studied, the tubes containing zinc were more active than those which did not contain zinc. When the serum was added, precipitation started at a concentration of about 1-1,000 and increased as the zinc increased through a maximum near a concentration of 1-150 with no immediate precipitate from a solution of 1-15 with respect to zinc sulfate.

From the summary of the data obtained in the study of yeast zymase, Table II indicates, with the exception of zinc sulfate and copper sulfate, that more antiseptic is necessary to produce complete inhibition in a 50% solution of normal horse serum than is required to produce complete inhibition in an aqueous solution. Whether the serum increases the activity of the yeast zymase or decreases the activity of the antiseptic or both is problematical. Those antiseptics for which no end point was reached generally showed a greater activity in serum when the same concentrations were used in both aqueous and serum media.

## Catalase

The general method of procedure was to determine the concentration or quantity of antiseptic required to completely inhibit the liberation of molecular oxygen from hydrogen peroxide by yeast catalase.

The yeast used was the ordinary small cakes made by the Fleischmann Yeast Company and secured every other day to assure fresh working suspensions. Two per cent solutions by weight were used throughout the study of catalase. It was made by suspending 4 gm. of yeast in enough distilled water to make the final volume 200 ml. This suspension was stored in a refrigerator at a temperature of approximately 5° C.

The following method of procedure was followed throughout the study of catalase. The desired amount of antiseptic was introduced into a test tube together with 2 ml. of a 2% yeast suspension and enough distilled water or serum added to make the final volume 10 ml. The tube content was then thoroughly agitated. After this mixture had been incubated for two hours at room temperature (about 23° C.), 2 ml. of 0.3N hydrogen peroxide was added. After mixing, the contents of each test tube were poured into a fermentation tube and incubated at room temperature for another hour. The smallest amount of antiseptic required to prevent the liberation of oxygen from the hydrogen peroxide was considered the end point of the experiment.

The antiseptic solutions used in the study of catalase were prepared in the same way as those used in the study of yeast zymase.

The hydrogen peroxide used was commercial peroxide manufactured by Coleman and Bell. A 0.3N solution was employed to determine whether or not the catalase had been destroyed. It was prepared by first standardizing a potassium permanganate solution and then titrating this solution against the unknown hydrogen peroxide solution. After determining the normality of the peroxide, the proper dilution was made by means of a burette.

The test solutions were made up and mixed in the following order: 2 ml. of the desired antiseptic solution, 2 ml. of a 2% yeast suspension, 6 ml. of distilled water or serum.

When those antiseptics which did not greatly retard enzymatic action were used, the ratio of the volume of water or serum to the volume of the antiseptic solution varied somewhat, but the total volume of antiseptic and water or serum was always maintained at 8 ml. The concentration and volume of yeast suspension never changed.

**Discussion of data obtained with catalase.**—Acriflavine was studied within concentration intervals of from 1-50 to 1-1,500 inclusive. In Table III is recorded a summary of the data obtained in this study of yeast catalase. In aqueous solution, all of the concentrations evolved more oxygen than samples which did not contain any antiseptic. Qualitatively, the greater the concentration of acriflavine, the greater was the evolution of oxygen. In the more concentrated solutions, however, the amount of gas given off seemed to become more constant. When serum was added, precipitation occurred in all tubes containing acriflavine. Concentrations contained about the same amount of oxygen as the tubes containing no antiseptic.

TABLE III.—A Summary of the Data Obtained in the Study of Yeast Catalase

| Antiseptic | End Point in Aqueous Sol. | End Point in Serum Sol. |
|---|---|---|
| Acriflavine | No inhibition | No inhibition |
| Alcohol | No inhibition | No inhibition |
| Argyrol | No inhibition | No inhibition |
| Carbolic Acid | 1-50 | 1-50 |
| Mercuric Chloride | 1-1000 | 1-150 |
| Metaphen | No inhibition | No inhibition |
| Neo-Silvol | No inhibition | No inhibition |
| Silver Nitrate | 1-6250 | 1-70 |
| S.T. 37 | 1-1250 | No inhibition |

In all concentrations studied below 60%, alcohol catalyzed the liberation of oxygen from hydrogen peroxide. Maximum activity appeared to be between 20% and 40% alcohol with a gradual decrease on both sides of this interval. When the serum was added, precipitation started near a concentration of 40% and increased as the amount of alcohol increased. Alcohol accelerated the reaction between the concentrations of 5% and 60% with maximum activity near 25% alcohol. Concentrations above 60% were less active than those tubes containing no alcohol.

All tubes containing argyrol were very active, denoting that the

colloidal silver which it contains promoted the liberation of oxygen from hydrogen peroxide. The reaction proceeded so rapidly, in aqueous solution, that it was practically complete before the solution could be transferred from the test tubes to the fermentation tubes. However, the argyrol was less active in serum medium than it was in aqueous solution. As the concentration of serum decreased and the concentration of argyrol increased, the activity increased accordingly. In a concentration of 10% argyrol and 40% serum, the reaction occurred almost instantaneously.

In aqueous solution, phenol acted catalytically between the concentrations of 1-75 and 1-1,000, the limits of this study. Maximum activity seemed to occur near a final concentration of 1-150. In serum medium, precipitation started at a concentration of approximately 1-75 and increased as the amount of phenol increased.

Mercuric chloride was studied in rather small intervals of concentration between dilutions of from 1-125 to 1-10,000. It was found, in aqueous solutions, that the salt increased the rate at which oxygen was liberated in solutions having concentrations between 1-4,500 and 1-10,000. In solutions stronger than 1-4,500, inhibition gradually increased with increasing concentration. The reaction was completely stopped near a concentration of 1-1,000. In serum medium, precipitation occurred with a bichloride concentration of about 1-750 and increased as the amount of salt was increased. Again the antiseptic increased the activity between the concentration 1-500 and 1-10,000.

In all concentrations of metaphen studied, from 1-625 to 1-10,000, inhibition was not observed. In aqueous solution, all concentrations within this interval liberated more oxygen than those tubes containing no metaphen. It appeared that there was a small increase in the amount of oxygen near a final concentration of 1-2,000. In serum medium, all tubes containing metaphen as well as those tubes not containing metaphen evolved about the same amount of oxygen.

In aqueous medium, the volume of oxygen increased as the concentration of neo-silvol increased between the concentrations 1-7 and 1-300. In a serum medium, the volume of oxygen remained fairly constant throughout this interval.

Silver nitrate, in aqueous solution, did not accelerate the reaction within the limits of the concentrations studied. Beginning with the most dilute concentration of the salt, 1-30,000, the volume of the oxygen liberated became less as the concentration of silver nitrate increased. In a serum medium, precipitation occurred near a concentration of 1-1,600 and increased as the amount of silver increased. In a serum medium, precipitation occurred near a concentration of 1-1,600 and increased as the amount of silver increased. All tubes containing serum with a dilution of antiseptic greater than 1-50 liberated about the same volume of oxygen after one hour as those tubes having no antiseptic. Those tubes containing silver nitrate seemed to react more rapidly at the beginning.

The activity of all concentrations of hexylresorcinol between 1-2,000 and 1-20,000 seemed to be fairly constant although in aqueous solution there did seem to be a slight increase in the volume of oxygen near a concentration of 1-2,500.

A review of the data obtained in the study of catalase, Table III, indicates, with the exception of carbolic acid, that more antiseptic is necessary to produce complete inhibition in an approximately 60% solution of normal horse serum than is required to produce complete inhibition in an aqueous solution. The same was observed in the study of yeast zymase, Table II.

## Pepsin

The pepsin used in this study was of the soluble type and furnished through the courtesy of Eli Lilly and Company, Indianapolis, Indiana. The solutions were prepared daily and stored in a refrigerator at a temperature of approximately 5° C. A 2% solution was used throughout which was made by dissolving 4 gm. of pepsin in sufficient distilled water to make the final volume 200 ml.

The other solutions used with pepsin were prepared in a manner similar to that employed in the study of yeast zymase and catalase.

Briefly, the general method of procedure consisted in determining the smallest amount of antiseptic that would prevent the digestion of "red" blood fibrin during a period of three hours.

The actual test solutions were prepared by mixing 2 ml. of the desired concentration of antiseptic, 4 ml. of distilled water, 2 ml. of buffer mixture, 2 ml. of a 2% solution of pepsin, and finally a few small pieces of "red" blood fibrin. The mixtures were then incubated for three hours at 38° C. The above portions were measured from freshly prepared solutions into test tubes by means of a pipette.

The buffer mixture was prepared according to the tables of Clark and Lubs by mixing 20.75 ml. of 0.2 N hydrochloric acid and 25 ml. of 0.2 N potassium chloride with enough distilled water to make 100 ml. This solution has a pH of 1.4.

The blood fibrin was dyed in a 2% aqueous solution of amaranth red for 30 minutes. All excess dye was then thoroughly removed by washing with water whose acidity had been previously adjusted to a pH of 3.0 with hydrochloric acid. This gave a red fibrin whose red color would not come out in acid media. Even the slightest digestion of the fibrin was made apparent by a noticeable red color in the test tubes. The dye and blood fibrin were obtained from Coleman and Bell, Norwood, Ohio.

When those antiseptics which did not greatly retard enzymatic action were used, the ratio of the volume of water to the volume of the antiseptic varied, but the total volume of the two was always maintained at 6 ml. Mercuric chloride and hexylresorcinol were the only antiseptics studied with pepsin.

A review of the data obtained in the study of pepsin indicated that for mercuric chloride the end point, in aqueous solution, is near a final concentration of 1-250. Hexylresorcinol was found not to inhibit pepsin activity.

Again it appeared that, in certain definite concentrations, mercuric chloride had some accelerating action. Apparently, more digestion of the fibrin took place near a concentration of 1-1,000 than at any other concentrations.

### Trypsin

The trypsin used was manufactured by Fairchild Brothers and Foster and was furnished through the courtesy of Eli Lilly and Company A 2% solution was prepared daily by suspending 4 gm. of trypsin in sufficient distilled water to bring the volume to 200 ml. The suspension was stored in the refrigerator.

Briefly, the general method of procedure consisted in determining the smallest amount of antiseptic that would prevent the digestion of "blue" blood fibrin during a period of three hours.

The actual test solutions were prepared by mixing 2 ml. of the desired concentration of antiseptic, 4 ml. of distilled water, 2 ml. of buffer mixture, 2 ml. of a 2% solution of trypsin, and finally a few small pieces of "blue" blood fibrin. The solutions were then incubated for three hours at 38° C. The above portions were measured from freshly prepared solutions into test tubes by means of a pipette.

The buffer solutions were prepared according to the table of Clark and Lubs by mixing 46.8 ml. of 0.1 N sodium hydroxide and 50 ml. of 0.1 molar monopotassium phosphate with distilled water to make 100 ml. This solution has a pH of 8.

The blood fibrin was dyed in a 2% solution of aniline blue for 30 minutes. All excess dye was then thoroughly removed by washing with water whose basidity had been previously adjusted to a pH of 8 with ammonium hydroxide. This gave a blue fibrin whose blue color would not come out in basic media. Even the slightest digestion of the fibrin was made apparent by a noticeable blue color in the test tubes.

Phenol was the only antiseptic studied in connection with trypsin. A review of the data obtained in the study of trypsin indicates that for phenol the end point, in aqueous solution, is near a final concentration of 1-50.

### Summary

A comprehensive and diversified study has been made concerning the influence of antiseptics upon enzymatic action.

The influence of alcohol, acriflavine, argyrol, boric acid, copper sulfate, carbolic acid, corrosive sublimate, ferric chloride, glycotanphene, lavoris, listerine, mercurochrome, merthiolate, neo-silvol, pepsodent, potassium permanganate, silver nitrate, hexylresorcinol, and zinc sulfate on yeast sugar fermentation, in aqueous media and in the presence of normal horse serum, has been studied. In all instances, with the exception of zinc sulfate and copper sulfate, it was found that more antiseptic was required to inhibit carbon dioxide formation in the presence of normal horse serum than was required to inhibit carbon dioxide formation in aqueous solution. The order in which the antiseptics prevented yeast sugar fermentation is given in descending order: mercuric chloride, silver nitrate, metaphen, hexylresorcinol, acriflavine, merthiolate, carbolic acid, mercurochrome, etc.

In the study of the influence of acriflavine, alcohol, argyrol, carbolic acid, mercuric chlorine, metaphen, neo-silvol, silver nitrate, and hexylresorcinol on catalase, in aqueous solution and in the presence of normal

horse serum, it was found, also, that, with the exception of carbolic acid, more antiseptic was required to prevent the liberation of molecular oxygen from hydrogen peroxide by the catalase in serum media than was required to prevent the liberation of oxygen from hydrogen peroxide by the catalase in aqueous solution. It was particularly observed that argyrol was much more active in an aqueous medium than in a serum medium.

In the study of the influence of mercuric chloride and hexylresorcinol on pepsin, it was found that much more antiseptic was required to enhance the action of pepsin than was required to inhibit the action of the other enzymes studied. A mercuric chloride concentration of 1-18,000 prevented yeast sugar fermentation; a concentration of 1-1,000 was required to stop the action of yeast catalase. It required a bichloride concentration of about 1-300 to inhibit the action of pepsin.

It was found that a carbolic acid concentration of 1-50 was necessary to prevent the digestive function of trypsin. The same concentration inhibited the liberation of oxygen from hydrogen peroxide; a concentration of 1-180 was required to stop yeast sugar fermentation.

From a survey of the data, it will be noted that, with two or three exceptions, much more antiseptic was required to inhibit the action of the enzymes in a serum medium than was required to prevent the action in an aqueous medium.

As a general rule, the antiseptics studied in this paper had a catalytic or promoting effect within a certain definite range of concentrations, and this effect was different for each enzyme.

# A Photographic Determination of the Relative Intensities of Three Chemiluminescences

Evans W. Cottman, Madison

In the present experiments, which were carried out in the laboratories of the Cleveland Clinic Foundation, measurements were made of the relative intensities of the luminescences resulting from the oxidation of urine, lophine (2, 4, 5-triphenylimidazole), and luminol (3-aminophthal hydrazide). The solutions used to produce the luminescence have been described in a previous article.[1] The light was maintained by means of the "lumistat," an automatic feeding device which maintains chemiluminescence at almost constant intensity. This device is to be the subject of a forthcoming article sometime in the near future. The lights were photographed on Eastman's Super XX roll film. A camera shutter was in each instance placed between the film and the light source to control the time of exposure. With this shutter interposed, the light source was about one inch from the film.

An exposure of 30 minutes was allowed for urine luminescence, 2 seconds for the lophine, and 0.08 seconds for the luminol. The densities produced on the film are shown in Table I and in Fig. 1. They were

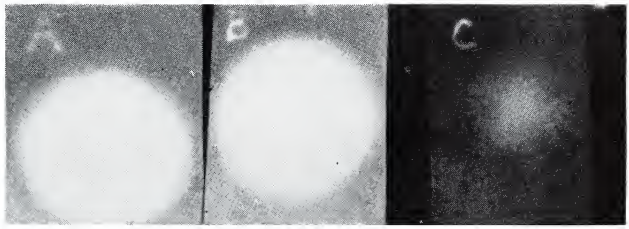


Fig. 1. A. Light from lophine, 2 sec.
B. Light from luminol, 0.08 sec.
C. Light from urine, 30 min.

Table I.

| Luminescent Material | Density | Log Exposure | Exposure | Time in Seconds | Intensity |
|---|---|---|---|---|---|
| Urine..... | 0.83 | $\bar{2}.43$ | 0.0269 | 1800 | $1.49 \times 10^{-5}$ |
| Lophine..... | 1.87 | $\bar{1}.54$ | 0.3468 | 2 | 0.173 |
| Luminol..... | 2.03 | $\bar{1}.74$ | 0.5495 | 0.08 | 6.87 |

[1]Cottman, Journ. Chem. Ed. 16:292-4 (1939).

measured on a densitometer of the Hartman type. The logs of the exposures were read from the proper H & D curves[2], and the exposures were determined. Assuming no reciprocity failure, $E=IT$, and $I=E/T$, in which I is the intensity, E is the exposure, as derived from the H & D curve, and T is the length of the exposure in seconds.

It may be determined from the data in Table I that the intensity of luminol luminescence is about $4.6 \times 10^5$ times as great as that of urine and about 40 times as great as that of lophine. Lophine luminescence is about $1.16 \times 10^1$ times as intense as that of urine.

## Summary

Through the use of photographic methods, determinations were made of the relative intensities of the chemiluminescence produced by the oxidation of luminol, lophine, and urine, respectively. Luminescence from luminol is about 460,000 times as bright as that from urine and about 40 times as bright as that from lophine.

[2]Supplied by the Eastman Kodak Company.

# The Action of the Esters of Chlorosulfonic Acid on Di-*n*-Butylamine

W. W. BINKLEY with ED. F. DEGERING, Purdue University

The reactions between the lower dialkylamines and the lower esters of chlorosulfonic acid at 0°C. were described by Delepine and Demars[1] in 1923. Similar reactions between the lower esters of chlorosulfonic acid and di-*n*-butylamine were conducted by Binkley and Degering in 1939.[2] The present study was an investigation of the reactions between the lower esters of chlorosulfonic acid and di-*n*-butylamine at the of these experiments are as follows:

A three-neck-distilling flask was equipped with a mercury-seal mechanical stirrer and a small dropping funnel. The third neck was attached to a gas analysis train containing four traps. The two traps nearest the reaction flask were surrounded by cold water baths while the other two traps were placed in dry ice-acetone baths. The apparatus was constructed in such a manner that a current of dry air could sweep any gases from the reaction flask into the gas analysis train. After one-fifth of a mole of di-*n*-butylamine was placed in the reaction flask, the agitation was begun. The flask was heated with a steam bath during the careful addition of one-tenth of a mole of the alkyl chlorosulfonate from the dropping funnel to the di-*n*-butylamine. The reaction mixture was heated for 30 minutes after the addition of the alkyl chlorosulfonate, while a slow current of dry air was allowed to pass through the apparatus. The cold water baths removed from the two traps nearest the reaction flask, these traps were warmed with steam to distill any volatile substances into the remaining two traps for analysis. The results of these experiments are as follows:

| Alkyl chlorosulfonate | Percentage of alkyl chloride formed (based on the alkyl chlorosulfonate used) |
|---|---|
| methyl | 60 |
| ethyl | 53 |
| *n*-propyl | 46 |

The oily residue in the reaction flask was largely di-*n*-butylammonium-*N*,*N*-di-*n*-butylamidosulfonate in all of these experiments. This compound was readily converted to di-*n*-butylamine hydrochloride and *N*,*N*-di-*n*-butylamidosulfonic acid (m.p. 132-3°C.) with hydrochloric acid.

## Conclusions

The reactions between lower esters of chlorosulfonic acid and di-*n*-butylamine at the temperatures of an ice bath and steam bath are markedly different as represented by the following equations:

$$RO.SO_2Cl + 2(n-C_4H_9)_2NH \xrightarrow[\text{bath}]{\text{ice}} RO.SO_2.N(n-C_4H_9)_2 + (n-C_4H_9)_2NH_2Cl$$

$$RO.SO_2.Cl + 2(n-C_4H_9)_2NH \xrightarrow[\text{bath}]{\text{steam}} R.Cl + (n-C_4H_9)_2NH_2O.SO_2.N(n-C_4H_9)_2$$

[1]Delepine, M., and R. Demars, 1923. *Bull. Sci. Pharmacol.* 30:577-9.

[2]A portion of a thesis submitted to the faculty of Purdue University in partial fulfillment of the requirements of the degree of Doctor of Philosophy, June, 1939.

# GEOLOGY AND GEOGRAPHY

Chairman: T. M. Bushnell, Purdue University

The program of this section was well attended, those present including a number of students of the State Teachers College. The two papers by Fred J. Breeze, listed by title below, were omitted because of the author's illness. The program was short, and the less hurried presentation of the papers permitted more discussion than usual.

W. D. Thornbury, Indiana University, was elected chairman of the section for 1940.

## ABSTRACTS

**The influence of the weather on crop yields in Indiana studied by the climograph technique.** Stephen S. Visher, Indiana University.—This is a study of the correlation between the yields of the various crops and such weather conditions as monthly average temperatures and rainfall totals, depth of snowfall, length of growing season, and number of days with temperature above 90°, over the period from 1887 to 1939, inclusive. The climographs show that monthly totals of rainfall and average temperatures affect crop yields to an extent which is surprising in view of the fact that the harvest depends upon several factors, including the weather of at least the entire period of growth. The departures from the monthly normals are, nevertheless, followed by rather consistent variations in yield. For wheat, Februaries which are drier than normal are advantageous, as are warmer Marches, cooler Mays, and winters with about 25 inches of snowfall. For oats, relatively cool Mays and wet, cool Junes and Julys are beneficial. For hay, relatively warm springs, wet Mays, and cool, wet Junes are advantageous. For corn, warm Mays and Junes and relatively cooler Julys and Augusts are desirable; more rainfall than Indiana's average amount is helpful to corn, especially in July and August.

The part of this paper concerned with corn appeared in *Indiana Farmers Guide* 95(1939):566. An extended discussion of these topics will appear as two chapters in a forthcoming volume, *The Climate of Indiana*.

**A plan for measuring the recession of Liston Creek Falls.** Fred J. Breeze, Fort Wayne Extension Center, Indiana University.—Published by title.

**1939, A centennial year in geology.** Fred J. Breeze, Fort Wayne Extension Center, Indiana University.—Published by title.

# The True Value of the Earth's Rotation as a Deflective Factor

A. V. Lott, Sellersburg

## Introduction

The deflective effect of the earth's rotation has been known and generally understood since the days of Ferrel. The laws of deflection have been established, and scientists generally believe that all air currents must obey those laws. Unfortunately, however, the acceptance of the earth's rotation as a deflective factor seems to have resulted in a general failure to give due consideration to any other deflective factors which may be present. Consequently, certain atmospheric movements have been attributed to the deflective effect of rotation when, in reality, they may have been due to factors, concerning which little definite information is available to students and average readers. This suggests the urgent need for a further study and a better understanding of all the factors which seem to work together to produce a deflection of air currents.

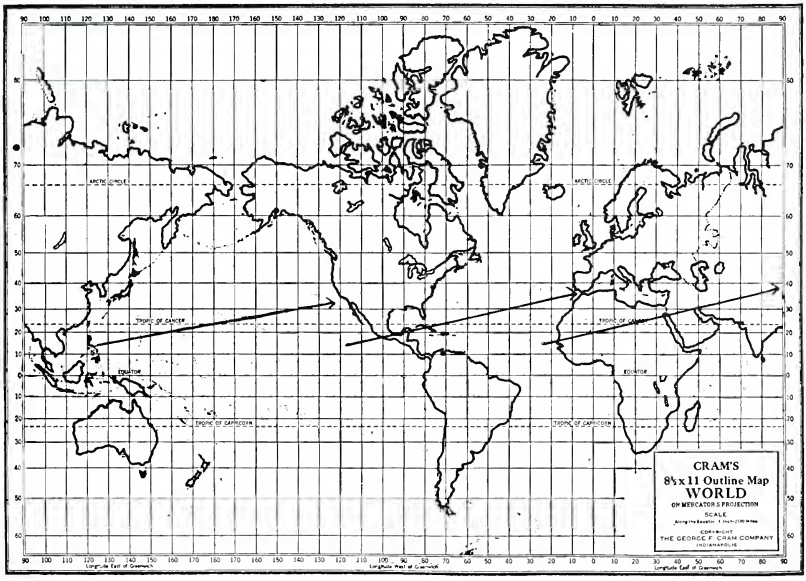


Fig. 1. Approximate positions and direction taken during years of sunspot minima of the three equatorial outflows moving into the northern hemisphere above the level of the surface winds.

Some evidence seems to indicate that the earth's rotation, when it acts alone, does not affect air currents in just the way that is now generally believed. Since the deflection seems to occur only when other

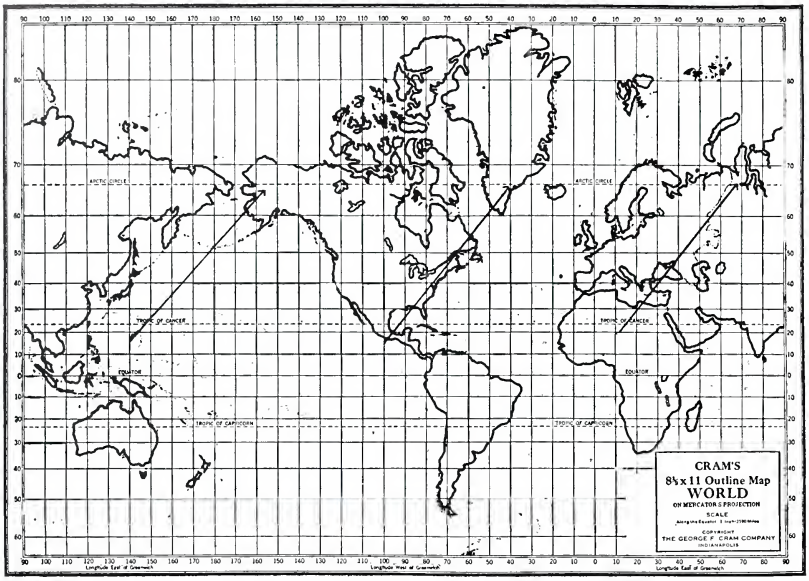


Fig. 2. Approximate positions and the direction taken during years of high sunspot maxima of the three equatorial outflows moving into the northern hemisphere.

factors are present, it is suggested that the observed deflection may be due, at least partly, to other factors. If further studies by other investigators should indicate that this possibility is really a fact, it would shed new light upon many problems that are now not fully understood.

Variations in the other factors which may affect deflection should cause or permit variations in deflection even when there is no appreciable change in the earth's period of axial rotation. It is the purpose of this paper to call attention to certain atmospheric movements which are said to be due to the deflective effect of rotation, to show why the accepted explanation is not altogether satisfactory, to direct attention to certain factors which seem to aid in causing deflection, to suggest a new interpretation of the observed phenomena, and to show how the new interpretation may lead to a better understanding of some problems that are not yet fully understood.

## Some Theoretical Effects of Rotation

When the deflective effect of the earth's rotation became generally understood and the theory became popular, all freely moving bodies were supposed to be affected. All air currents had to be affected. Some believed that the courses of ocean currents were affected. Others asserted that the water in the rivers bore more heavily upon the right bank than upon the left. The rotatory circulations around cyclones and anticyclones were attributed to the effect of the earth's rotation. When the southeast trade winds crossed the equator they were said to be deflected toward the right, and the major movements of the general

atmospheric circulation, the easterly winds of low latitudes and the westerly winds of higher latitudes, were considered to be due to this deflective effect upon air currents moving between the equator and the poles.

These beliefs have been modified to some extent. Some scientists now readily admit that only air currents are appreciably affected, and probably not all of these. However, the great majority seem to believe that the effect of the earth's rotation is very real and that all air-flows must obey the laws of deflection.

### Objections to the Accepted Theory

Scientists once believed that every air-flow that occurred was, in one way or another, the result of some convectional movement. The convectional theory of cyclonic formation was widely accepted. Briefly, the theory required an updraft of air with a horizontal current flowing at the top to carry away the rising air currents. Air was supposed to flow in from the surrounding areas toward the center of greatest activity, the inflowing currents being deflected toward the right in one hemisphere and toward the left in the other, producing the familiar rotatory movement of the cyclonic circulation.

This theory seemed to be fairly satisfactory for a time, especially in accounting for the formation of extra-tropical cyclones, but it could not give an adequate explanation for the cyclones of tropical origin. Cloudy, unsettled weather with showers, squalls, and irregular winds often prevailed throughout large areas in the hot humid sections of the tropical oceans. Theoretically, the conditions seemed favorable for cyclonic formation; yet the cyclonic circulation did not always develop. Since the earth rotates continually, the deflective effect of rotation should be ever-present. The frequent failure of the cyclonic circulation to develop seemed to indicate that rotation was an effective deflective factor only when all conditions were right. It also indicated the possible presence of some other factor which could assist the earth's rotation in producing the rotatory movement.

The convectional theory of cyclonic formation was followed by the polar frontal theory, which became increasingly popular following the advent of a new method of weather forecasting known as air mass analysis. The new theory seemed to offer a more satisfactory explanation of cyclonic formation, but difficulties were encountered in explaining the formation of tropical cyclones owing to the slight temperature discontinuity which prevailed in the lower latitudes. Some of these difficulties seem to have been removed by Scofield's suggestion (1) that "the temperature discontinuity must be slight and the wind discontinuity great."

The idea that tropical cyclones were of frontal origin was first established by Bjerknes in 1920, and there seems to be a growing tendency among meteorologists to accept this view. The term "frontal origin" should not be confused with the term "polar frontal origin." The polar front approaches from the northwest and is made up of polar continental or polar marine air. The term "frontal" may include the tropical fronts which mark the boundary between the trade winds of the oceanic

anticyclones and the doldrums or, if the doldrums are absent, the boundary between the northeast trades and the southeast trades. The north tropical front is most clearly defined when the Bermuda-Azores High is very strongly developed. Tropical cyclones form in certain favorable areas and move along this front during the period when the pressure gradient is unusually strong. The unusual pressure gradient may have great significance. It may be the factor which assists the earth's rotation in producing the rotatory movement.

Deppermann (2), when discussing the typhoons that originate in the China Sea, concludes that the typhoon "arises at the junction of two or more of the main air streams, such as the trades, northers and southwest monsoon." According to this conclusion, the cyclonic circulation cannot be due to deflection of air currents directly to the right by the earth's rotation. It seems to be the natural result of converging air currents that move in nearly opposite directions.

Algue (3), after observing the formation of tropical cyclones in western Pacific waters for more than twenty years, concluded that the cyclone formed "neither in a region of low nor in a region of high pressure but in a neutral zone." A study of the pressure charts for the western Pacific and the adjoining areas of eastern Asia shows that the neutral zone was always bounded by one or more anticyclonic fronts. Air currents from these fronts could have been the direct cause of the rotatory movement.

Deppermann (2) makes the further suggestion that the typhoon may possibly arise from a surge of the trade throwing the front farther south than usual, against the opposition of the southwest monsoon. The results of such a surge or sudden extension of a front will be clearly understood after observing the following simple experiment: A deep basin is filled with water, the hand is completely submerged and given, from the wrist outward, a sudden movement toward the right. This movement represents the surge or sudden extension of a front. If the hand is in the proper position relative to the surface of the water, an eddy will form just beyond the fingers and move obliquely toward the right. This eddy always whirls in an anticlockwise direction. It is practically identical with the familiar rotatory circulation that surrounds the cyclonic storms of the northern hemisphere.

When the water has quieted, the experiment is repeated by moving the hand toward the left. A clockwise eddy forms and moves obliquely toward the left. Its whirling motion is practically identical with the circulation that surrounds the cyclonic storms of the southern hemisphere.

This experiment shows clearly that the cyclonic circulation may be the direct result of frontal action. It may be produced without any assistance from the earth's rotation.

These evidences and others found in the literature do not give satisfactory support to the view that the rotatory motion is the result of a direct deflection to the right in one hemisphere and toward the left in the other. If the earth's rotation is a factor in cyclonic formation at all, it must act indirectly and through the formation of anticyclonic fronts which move toward the right in the northern hemisphere and toward the left in the southern hemisphere.

Algue (3), who was once Director of the Philippine Weather Bureau, wrote at length on the normal winds of the Philippine Archipelago. He concluded that the southwest winds which sometimes prevailed in that area were not deflected southeast trades but winds of a cyclonic character. The proximity of this area to the region where the southwest monsoon is most fully developed seems to support his view. The winds in this region are not only affected by the Asiatic land mass but also by the Asiatic thermal depression. The winds at higher levels may also have some effect upon the surface circulation. Theoretically, a terminal anticyclone should lie over Asia during the summer months. The anticyclonic winds which should blow at higher levels, when aided by the geographical conditions that are found in that area, could conceivably produce cyclonic winds at the surface. When all things are considered, it seems unwise to attribute the observed circulation to the deflective effect of rotation until after due consideration has been given to the other possible factors.

Deflection seems to be a factor of major importance in determining world climates. Climatic changes of great magnitude possibly could not occur if rotation were the only or even the major deflective factor. The major winds of the general circulation now blow in a general east-west direction. Consequently, belts of similar temperatures also tend to develop in a general east-west direction, and the warm air of a given latitude tends to remain near that latitude. Some of the equatorial heat escapes upward and outward through the antitrades but this heat is carried eastward by the westerly winds. Some heat from the same region also escapes through the warm ocean currents, but they also are deflected eastward under the influence of the westerly winds. These conditions tend to produce a world climate that is marked by climatic zones. The formation of climatic zones seems thus to be partly due to the fact that the warm air and ocean currents from lower latitudes are deflected eastward before they reach the polar regions. If these currents were not deflected eastward, a period of relative climatic uniformity might prevail because the higher temperatures from lower latitudes would then be carried directly to higher latitudes. It seems, therefore, that deflection is a very important climatic factor. If the deflection is due mainly to the earth's rotation, world climates must have been marked by climatic zones throughout all the ages of earth history. Some modification of the zonal climate could have occurred as a result of changes in geographical conditions. Further modification could have occurred as a result of variations in the earth's period of axial rotation. Yet the climatic zones must have persisted from age to age. It seems that this would cause the normal climate of the polar regions to be either cool or cold. Warm climates in those regions would occur only under unusual geographical conditions. Yet mild climates have prevailed in polar regions throughout long periods and under geographical conditions that were apparently not especially favorable for the movement of warm ocean currents into such high latitudes.

Scientists generally recognize the difficulty of making an adequate explanation for the occurrence of such mild climates in the higher latitudes. Some feel that the problem is inexplicable. Many do not realize

that much of the difficulty lies not in the problem itself but in the theory of circulation that is now generally accepted. More recent studies (4) of the general circulation indicate that it is a very complex phenomenon, but many scientists still cling to the earlier conclusions which held that the warm currents which move from the equator toward the poles must be deflected toward the right in one hemisphere and toward the left in the other as a result of the earth's rotation. Therefore, these warm currents can never reach the polar regions. If the old theory is correct, climatic changes of great magnitude are difficult to explain. The changes must necessarily be generally slight.

Scientists who have studied the matter have accumulated such a mass of evidence which points to climatic changes of great magnitude that such changes can no longer be doubted. The fact that the marked changes have occurred seems to support the view that deflection has not always been as great as it is today. In other words, rotation cannot be the only or even the major factor affecting deflection.

Several investigators have, without questioning the value of the earth's rotation as a deflective factor, attempted to show how the major climatic changes could have occurred. Their explanations include changes in the earth's orbital elements, continental drift, reversal of the deep sea circulation, changes in the oblateness of the earth, emission of solar electrons, changes in geographical conditions or land elevation, and other theories and hypotheses. This wide diversity of opinion among geologists and climatologists may be due to the fact that too much importance has been ascribed to the earth's rotation as a deflective factor.

Further evidence which seems to question the value of rotation as a deflective factor is found in the fact that the most important airflows in the world do not fully obey the established laws of deflection. Deflection is supposed to vary directly with the latitude and inversely with the velocity of the moving current. Evidence hitherto largely ignored suggests that it varies directly with the velocity of the general circulation rather than inversely with the velocity of the moving current.

The general circulation of the atmosphere is usually attributed primarily to the temperature inequality between the equator and the poles, the cold, heavy air from the higher latitudes presumably flowing toward the equator, while the warm lighter air rises in the equatorial region. Scientists once believed that the warm, lighter air rose to the top of the atmosphere and moved away into the higher latitudes as an overflow, but further studies revealed the astonishing fact that the warm air did not rise to the top of the atmosphere. Temperature recordings made by balloons sent aloft in different areas showed that the lowest recorded temperatures at high altitudes were found in the equatorial region, while somewhat higher temperatures were recorded at the same altitudes in the polar regions. This suggested that air currents in the stratosphere were descending in the equatorial region and rising at the poles. The circulation in the stratosphere has been described as a "mirror image" of the circulation that exists in the

troposphere. In other words, according to present knowledge, the air at the top of the atmosphere moves from the polar regions toward the equator and then descends until it meets the warm air of the equatorial region which rises from below. The two currents then unite and move outward into the higher latitudes through the antitrades. This outflow from the equatorial region is not uniform throughout the earth's circumference, but, rather, it seems to flow in greater volume through three separate streams into the northern hemisphere. These three streams, with other similar streams that flow into the southern hemisphere, may be called the most important air-flows in the world because they are important factors in the formation of world climates. The air which flows outward through these streams moves obliquely downward toward the surface of the earth and forms belts of increased pressure near latitudes 30 degrees north and south of the equator and then continues onward into the higher latitudes as the westerly winds.

When air flows into a region, it causes an increase in the atmospheric pressure within that region unless this is counterbalanced by an outflow. If the inflow is greater than the outflow it should result in increased pressure until the air eventually breaks through at the weakest point and flows outward. A further flow into the region should cause the pressure to build up again, and the process might continue indefinitely.

The three atmospheric streams flowing into the middle and higher latitudes of the northern hemisphere should, theoretically, produce there a higher atmospheric pressure. During this particular age of earth history one of these equatorial outflows seems to terminate in the North Pacific, forming an area of increased pressure that usually lies between the Hawaiian Islands and the western coast of North America. It may be identified as the North Pacific anticyclone. This area of high pressure seems gradually to increase in intensity until a mass of air breaks away and moves eastward with the prevailing winds. The Pacific anticyclone then decreases in intensity, but it gradually builds up again until another mass breaks away and moves eastward as a migratory anticyclone. This process continues indefinitely.

The Pacific anticyclone does not always remain in a fixed position. Its outflowing currents which take the form of migratory anticyclones sometimes move northeastward or northward instead of eastward. The anticyclone does not always extend over its normal oceanic area but may reach eastward, forming the Great Basin anticyclone. When it extends so far eastward, it is usually associated with a greater number of deep lows that move rapidly eastward along the northern border of the United States. When the anticyclone does not extend eastward over the land area, it seems to be associated with a lesser number of lows which are usually of lesser intensity and which do not move so rapidly nor so directly eastward. When the anticyclone feeds northward toward Alaska, it seems to be associated with lows which move rather slowly more nearly from north to south than eastward. These associations seem to indicate that the position of the anticyclone and the direction taken by its outflowing current must be related in some way to the strength or the velocity of the inflowing stream. If the in-

flowing stream is stronger than normal or if it is flowing at a greater than normal velocity, it seems to terminate farther eastward, and the associated conditions suggest a more active general circulation. If the atmospheric stream is weaker than normal or if it is flowing at a subnormal velocity, it seems to feed northward toward Alaska, and the associated conditions suggest a more sluggish general circulation.

These observations seem to indicate that a strong or active equatorial outflow is deflected eastward more rapidly than a slower outflow. In other words, the deflection of the equatorial outflow varies directly with the velocity of the general circulation.

Deflection is supposed to vary inversely with the velocity of the moving current; that is, the greater the velocity, the less is the deflection from a straight course, and the less the velocity, the greater is the deflection. These theoretical movements are in direct opposition to the movements that have been actually observed. This discrepancy indicates that the entire subject should be given further consideration and suggests that the earth's rotation may not be the only or even the major factor which causes the deflection.

### Factors Which Cause Deflection

In none of the cases which have been considered can the observed deflection be attributed positively to the earth's rotation. The rotatory motion of cyclonic storms seems to be the result of frontal action rather than a direct effect of rotation. The deflection of the southeast trades, wherever it occurs, seems to be due, at least partly, to the proximity of anticyclonic winds, large land masses, or thermal depressions, or to some interference in the circulation, due to mountain ranges, islands, etc. The variations in deflection that seem to correspond with variations in the velocity of the general circulation are clearly not due to variations in the earth's period of rotation but to other factors. Any factor which may affect the velocity of the easterly winds of the lower latitudes or of the westerly winds of the higher latitudes may also cause variations in the deflection of these outflows. In other words, a cyclone of great intensity could increase wind velocity over a wide area and thus cause temporary variations in deflection.

The deflective factors which have been considered may be regarded as of minor importance as compared with another, namely, solar activity. The writer has observed that the oceanic anticyclones seem to feed more directly eastward during periods of sunspot minima and more directly into the higher latitudes during years of sunspot maxima. The observations on this point have not covered the full sunspot cycle, but a search of the literature reveals some recent and very interesting investigations made by Clayton.

Clayton (5) investigated the relation between the eleven-year sunspot cycle and changes in atmospheric pressure, noting the departures from the annual means of pressures for about 200 stations scattered over the earth, as given in World Weather Records. When these data were plotted on maps of the world, they showed a tendency toward excess pressures in middle latitudes over the oceans and somewhat lower pressures over tropical lands and oceans at the time of sunspot maximum.

They also showed that the areas of excess pressure over the oceans were displaced northward with each increase in intensity in the sunspot maxima. When there was distinct evidence of excess pressure in middle latitudes over the Atlantic Ocean, there was a deficiency over a large part of the land areas.

These findings suggest an east-west elongation of the Atlantic anticyclone at the time of sunspot minimum. This east-west elongation seemed gradually to develop into a north-south elongation with each increase in intensity in the sunspot maxima. The north-south development over the ocean apparently was associated with a withdrawal of pressure from adjoining land areas.

Clayton's maps showed that the baroplion or area of excess pressure lay in high latitudes during years of high sunspot activity. In 1916-17 the baroplion lay above latitude 65°. It moved to lower latitudes in step with decreasing solar activity, and in 1923 it lay at about 30° latitude. The same progressive movement occurred throughout the eleven-year cycle. The maximum of pressure at Jacobshavn (Greenland) and at Haparanda (North Sweden) coincided with the sunspot maximum, but the pressure maximum occurred successively later at stations to the southwest until at Madeira and Helwan the maximum of pressure occurred at sunspot minimum. Also at Tanana, in Alaska, the maximum of pressure occurred at the time of sunspot maximum and successively later southward to San Diego.

Clayton's findings indicate that there is a real relation between solar activity and the areas of excess pressure that lie in middle and higher latitudes. This writer believes that these areas of excess pressure form in the region that immediately surrounds the ends of the equatorial outflows. These findings, when taken in connection with the writer's observations and interpretation, are illustrated in Figures 1 and 2. Figure 1 shows the approximate positions at the time of sunspot minimum of the three equatorial outflows moving into the northern hemisphere. Figure 2 shows the approximate positions of the same outflows at the time of sunspot maximum. These illustrations seem to show that the equatorial outflows suffer a greater deflection eastward during the period of sunspot minimum and a lesser deflection eastward during the period of sunspot maximum. Here is a variation in deflection which seems to be related to variations in solar activity. The deflection increases as solar activity diminishes and decreases as solar activity increases. In other words, the deflection of the equatorial outflows varies inversely with variations in solar activity.

This evidence suggests that solar activity must be considered as one of the factors which cause the deflection of air currents. The observed variations in solar activity have been relatively slight yet the variations in the deflection of the equatorial outflows have been relatively great. This indicates that solar activity may be a major deflective factor and may rank above the earth's rotation in importance. It is the opinion of this writer that the evidence does not give satisfactory support to the view that air currents are deflected to the right in the northern hemisphere and to the left in the southern hemisphere as a result of the earth's rotation. Much of the deflection that has

formerly been attributed to rotation seems to be due directly to the effects of solar radiation.

### A New Interpretation

The exact manner in which solar radiation acts to produce a deflection of air currents is not clear. Only the results are apparent. Variations in solar activity cause corresponding variations in the total output of solar radiation. Increasing solar activity seems to reduce the radiation of those frequencies which affect the velocity of the general circulation, and, consequently, the equatorial outflows move more directly toward the poles. Decreasing solar activity seems to permit a greater radiation of the frequencies which affect the velocity of the general circulation, and the equatorial outflows then develop more rapidly eastward. Air currents may be deflected by several factors, but solar radiation seems to be the primary one. Any factor which interferes with or weakens the effective frequencies of solar radiation before they reach the earth's atmosphere, such as increasing sunspot activity or increasing distance between the earth and the sun, may cause these deflections.

The evidence does not indicate that, when acting alone, either the earth's rotation or solar radiation causes the deflection. It seems that solar radiation and the earth's rotation work together to produce a deflection toward the right in one hemisphere and toward the left in the other, this tending to produce a longitudinal circulation with east-west movements predominating. Factors which weaken solar radiation decrease the deflection, and this tends to produce a latitudinal circulation with north-south movements predominating. These variations in deflection may result in weather and climatic changes of the most astonishing character.

### Importance of This Interpretation

This interpretation should lead to a better understanding of the major movements of the general circulation. It suggests that the general circulation may be divided into individual units, all of which are formed according to the same general pattern. Each unit seems to be formed around an atmospheric stream that flows out of the equatorial region and terminates in an anticyclone in middle or higher latitudes. Three such streams move from the equatorial region outward into the higher latitudes of each hemisphere. In the northern hemisphere one stream leaves the equatorial region in the lower latitudes of the eastern Atlantic and terminates in the Asiatic anticyclone. A second stream moves outward from the equatorial region in the lower latitudes of the western Pacific and terminates in the Pacific anticyclone. A third stream moves outward from the lower latitudes of the eastern Pacific and terminates in the Atlantic anticyclone.

The terminal anticyclone of each stream makes contact with the equatorial air in the outflow adjoining it on the east. The line of contact between the cold front of the terminal anticyclone and the warm front of the next outflow becomes a region of cyclogenesis. The cyclones thus formed are carried along in the air-flow of the unit. The air which

leaves the equatorial region and flows into the terminal anticyclone causes that air mass to increase in intensity until a mass of air breaks away from the terminal area and moves into the next unit as a migratory anticyclone. This procedure continues indefinitely. Thus the equatorial outflow with its terminal anticyclone and the attendant migratory pressure formations constitute an individual unit.

The air-flow over the North Pacific ocean furnishes an excellent example of such a unit. This seems to begin in the lower latitudes of the western Pacific and terminates in an anticyclone in the northeast Pacific. The line of contact between the Asiatic anticyclone and the warm air of the Pacific outflow becomes a region of cyclogenesis. The cyclones thus formed are carried along in the air-flow of the Pacific unit, and air masses that break away from the Asiatic terminal area move into the Pacific unit as migratory anticyclones. All migratory pressure formations are carried along in the Pacific outflow directly toward North America. They usually enter the continent from the northwest and continue their movement in approximately a straight line until they drift into the equatorial outflow of the next unit. The migratory formations then move in the direction followed by the American outflow which carries them toward northwestern Europe.

The line of contact between the cold front of the Pacific terminal anticyclone and the warm air of the next unit becomes another region of cyclogenesis. The cyclones which are thus formed usually move from the southwest toward the northeast, being carried along in the air-flow of the unit. This outflow terminates over the eastern Atlantic.

In years of sunspot minima the three terminal anticyclones form between latitudes 30° N. and 40° N. They become elongated in an east-west direction and tend to form a ridge of increased pressure that completely encircles the earth. The migratory cyclones roll rapidly along this ridge on its northern side. This is the typical longitudinal circulation. Increasing solar activity is accompanied by a lesser deflection of the equatorial outflows. Consequently, each terminal anticyclone forms in higher latitudes, and each movement into the higher latitudes is accompanied by lower temperatures in the terminal area. The west-to-east flow into the terminal area changes to a southwest-to-northeast flow, while the west to east flow out of the terminal area becomes a northwest-to-southeast movement. This shows a tendency for the longitudinal circulation to develop into a latitudinal circulation with north-south movements predominating.

Each successive increase in solar activity seems to cause a further decrease in the deflection of the equatorial outflows with a further movement of the terminal anticyclones toward the north and a further development of the latitudinal or north-south circulation. The terminal anticyclones, with their areas of increased pressure, eventually move into the areas that are now occupied by the oceanic areas of low atmospheric pressure. This causes a reversal of pressure conditions, the migratory and permanent cyclones being crowded southward, while high pressure fills the normal low pressure lane. Cyclones can then freely draw in warm, moisture-laden air from low latitudes and carry it directly into the cold front of the terminal anticyclones in high lati-

tudes. This results in unusually stormy conditions with low temperatures and heavy snowfall.

According to the preliminary investigations made by the writer, a continued movement of the terminal anticyclones into the higher latitudes should lead to the formation of cold fronts in low latitudes, possibly accompanied by glaciation in certain areas if geographical conditions were favorable. The complete development of a latitudinal circulation should bring on a period of climatic uniformity.

## Conclusions

The importance of the earth's rotation as a deflective factor has apparently been over-emphasized. Air currents may be deflected by several factors. Solar radiation and the earth's rotation, by working together, seem to cause a deflection of the major atmospheric streams that flow from the equatorial region into the higher latitudes. Variations in the effective frequencies of solar radiation permit variations in the deflection of the equatorial outflows. These variations in deflection may result in weather and climatic changes of significance.

## Literature Cited

1. Scofield, Edna, 1938. On the origin of tropical cyclones. Bull. Amer. Meteorol. Soc. 19:244.256.

2. Deppermann, C. E., 1938. Typhoons originating in the China sea. Philippine Weather Bur. Excerpts, Bull. Amer. Meteorol. Soc. 19:375-377.

3. Algue, Jose, 1904. The cyclones of the Far East. Philippine Weather Bur.

4. Barlow, E. W., 1931. The present positions of theories of the circulation of the atmosphere. Quart. Journ. Royal Meteorol. Soc. 57:3-12.

5. Clayton, H. Helm, 1938. The sunspot period in atmospheric pressure. Bull. Amer. Meteorol. Soc. 19:218-221.

# Glacial Lakes Quincy and Eminence

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It is the purpose of this paper to discuss the origin and development of two glacial lakes which occupied portions of Owen, Morgan, Putnam, and Hendricks counties during the Illinoian and Wisconsin glacial stages. The existence of these lakes is indicated by the presence of extensive lacustrine flats in the area under discussion. The presence of these lake plains was recognized by early geologists, but no careful study has previously been made of their areal distribution, origin, or ages. The location of the area discussed in this paper is shown in Figure 1.

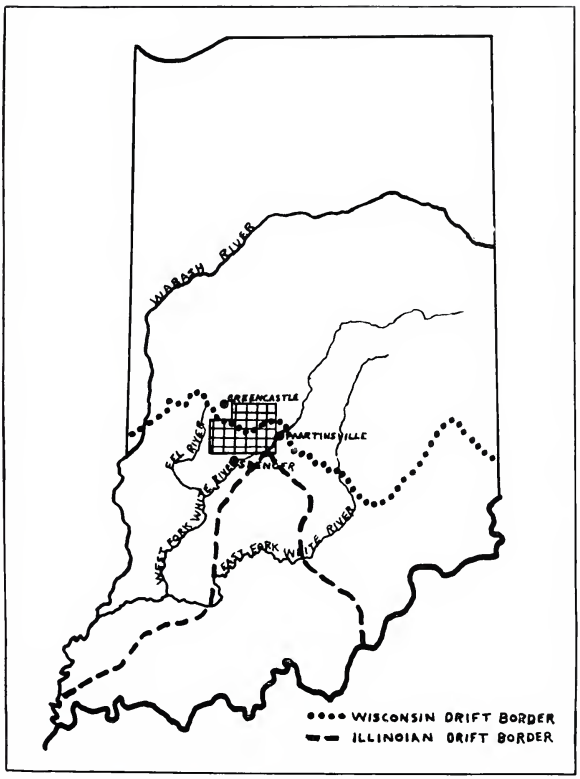


Fig. 1. Outline map of Indiana showing location of area under discussion and its position with respect to the Illinoian and Wisconsin drift borders.

## Glacial Lake Quincy

**Early descriptions of Lake Quincy.**—The name Lake Quincy[1] is proposed for one of these glacial lakes. The site of the lake so named is now marked by a lacustrine plain covering between 40 and 50 square miles lying in portions of northeastern Owen, southeastern Putnam, and western Morgan counties. The name is taken from the small village of Quincy in northeastern Owen County, where extensive portions of the lacustrine plain are still preserved.

Probably the earliest reference to what is here called Lake Quincy was made by Collett.[2] In his discussion of the effects of the Glacial Epoch upon the geology of Owen County, he says:

"For a probably short time the ice sheet extended over nearly the entire area of the county. . . . It is probable that the foot of the ice flow for a long time lodged, and was heaped up against the ridge running east and west through Spangler's hill just south of Cataract, where the wintry accumulation was melted and discharged down Mill, Rattlesnake, Fish, and Lick creek valleys. . . . Today a cut of less than 70 feet would carry the water of Eel River, above the falls, into Rattlesnake Creek, its old channel. . . .

"That the valleys of Eel, below the cataracts, and White river, below the mouth of McCormack creek, are recent, much more recent than that above, is obvious. They are at once contracted to from one-fourth to one-twentieth their former width, that is, the width of the ancient channel higher up stream. The question at once arises, how was the new channel obtained? During the evident long period that the foot of the glacier rested against Cataract ridge and the highlands in the north part of Monroe county, the continuous retreating and advancing process of the ice scooped out a deep, wide basin in White river, east of Gosport, and north and east of Cataract, just as the basins of the lakes were excavated far below the river and outlet. As the ice by climatic change withdrew to the north, these basins became sluggish streams, or filled by the excessive precipitation common in cold regions, temporary lakes. . . ."

". . . . Wells dug in the valley plain, between Quincy and Cataract, in the old river bed leading to the 'flat woods,' and in the wide bottoms above Gosport, indicate beds of laminated sand and muck of lacustral character."

Malott[3] in discussing the physiography of the Mitchell plain in this section of Indiana recognizes the existence of extensive lake deposits in this area and states:

"The Mitchell plain north of Ellettsville in northwestern Monroe County has been modified by glaciation. The chief effect of glaciation has been to mantle the rather dissected and locally nearly destroyed plain with glacial material, and eventually farther north to cover over and entirely obscure the plain. Locally, where the plain has been deeply dissected by surface streams, it has been restored to its original level by glacial

[1]This represents the formal proposal of the name Lake Quincy for the lacustrine area which occupies portions of northeastern Owen, southeastern Putnam, and western Morgan counties. The naming of this lake area, however, should be attribuuted to Dr. C. A. Malott, of the department of Geology and Geography of Indiana University. In the Handbook of Indiana Geology (P. 210) he refers to this lake region but does not give it a name. He seems to have adopted the name Lake Quincy for this region in his own usage, for A. R. Addington, in a paper on Porter's Cave, which is located just east of the Lake Quincy lacustrine plain, refers to this lake region as Lake Quincy as if it had already been so named. Addington's paper was published in 1927, five years after the Handbook of Indiana Geology appeared. It thus appears that the use of the name Lake Quincy had been informally adopted by both Malott and Addington as a result of their verbal discussions of the area. They were both members of the geology staff at Indiana University.

[2]Collett, John, 1875. The Geology of Owen County. Indiana Geol. Surv. Ann. Rept. 7:306-307.

[3]Malott, C. A., 1922. Handbook of Indiana Geology. Pp. 210-211.

material chiefly in the form of lake deposits. Two areas of this kind are of more than ordinary interest. One of these, known as the Flatwoods, lies chiefly in Monroe and Owen counties. . . .

"The other lake area developed in part on the Mitchell plain is quite extensive. It lies along Mill Creek, or Eel River, in northwestern Owen, southeastern Putnam, northwestern Morgan, and southwestern Hendricks counties. It is terminated at its western edge by the double fall of Mill Creek, or Eel River. The lake plain above the fall of Eel River is approximately on the level of the Mitchell plain, which was largely removed in this locality by stream dissection before the region was glaciated. The area of the former lake, or the area affected by ponded drainage conditions, was 50 square miles or more. The altitude of the present lake flat, or lacustrine plain, is 750 to 775 feet. Portions of the Mitchell limestone plain are seen about the margin of the silt-covered area.

"The lacustrine plain above the falls of Eel River is due principally to the obstruction of the pre-Illinoian Mill Creek, or Eel River, in the vicinity of Cataract in northeastern Owen County. The Illinoian glacier completely filled the entrenched valley in this locality to or somewhat above the level of the upland Mitchell plain surface. Following the retreat of the ice the waters in the drainage basin above, which also was probably somewhat modified, found outlet at the level of the bedrock surface high above the old entrenched valley. The waters, however, re-entered the old valley somewhat lower down. Falls were formed where the accumulated waters of the basin above entered the old entrenched valley. In time the basin of the ponded drainage became filled to the level of the bed-rock surface of the stream above the falls, thus giving rise to a lacustrine plain. Inwash in the upper portions of this lacustrine plain has built it up still higher. Portions of it are very flat and poorly drained, as for example along Mud Creek in northwestern Morgan County. This locality west of Monrovia and north of Eminence is known as 'The Lakes' or the 'Lake Country.'

"The falls of Eel River near Cataract are very picturesque. The descent of the stream into the entrenched valley takes place over a stretch of a mile or more, and in a series of rapids, and two falls of approximately 25 feet each, a total descent of nearly 100 feet occurs. Picturesque gorges of several hundred yards in length occur below each of the falls.

"It is not known what influence the Wisconsin glaciation had on the lacustrine plain above the falls of Eel River. Possibly part of the plain itself is due to the Wisconsin glaciation. Few details concerning the region are at present available. A possible connection of the pre-Illinoian Eel River with Rattlesnake Creek has been suggested, but it is not likely that any such connection existed."

Another reference to Lake Quincy is found in Addington's[4] discussion of the relation of Porter's Cave, which lies just beyond the eastern edge of the Lake Quincy lacustrine plain, to glaciation in that area. Addington states:

"The area is marginal to the Early Wisconsin Drift. Along the margins of this drift Glacial Lake Quincy had its inception. Similar to any marginal lake formed along the border of an ice mass, this lake had a number of overflow outlets. The positional relation of the lake flat to the Porter's Cave region is such as to suggest a partial escape for the lake waters in the vicinity of the cave.

"If it is not too much speculating I venture the suggestion that during a short period overflow from the lake was by way of the valley now abandoned and at the same time part of the waters were escaping by subterranean passages along the route of the cave, the subterranean routes receiving more water than they could transmit.

"The abandonment of the valley by the stream and the diversion of the waters to subterranean routes would come as a result of lessened supply due to the lake finding a lower outlet. If this assumption is correct, the drainage condition near the cave had its inception during the Early Wisconsin Glacial Stage.

"Before the exact relation of Lake Quincy to the Porter's Cave region can be ascertained, a detailed study of the lake basin with a view of determining the various overflow outlets will be necessary. This in itself is no small matter. . . ."

[4]Addington, A. R, 1927. Porter's Cave and recent drainage adjustments in its vicinity. Proc. Indiana Acad. Sci. **36**:116-117.

It was for the purpose of supplying more details concerning the Lake Quincy area in order to work out its history that the present study was undertaken.

**Description and history of Lake Quincy.**—Glacial Lake Quincy developed as a pro-morainal or marginal lake in front of the Illinoian ice sheet due to the ponding of the southwest drainage of Mill Creek.[5] Mill Creek apparently drained in somewhat the same general direction to the southwest, as at present, prior to the Illinoian glaciation. The damming of Mill Creek occurred in the neighborhood of the village of Cunot in northwestern Owen County. The lacustrine deposits which accumulated in Lake Quincy can be traced down the valley of Mill Creek to a point just about one mile southwest of Cunot in Section 28, T. 12 N., R. 4 W. This moranial dam was approximately three miles below the present site of the upper Cataract Falls on Mill Creek.

The maximum areal extent of Lake Quincy is shown in Figure 2. This map represents fairly accurately the areal extent of Lake Quincy but may not be correct in every detail, as no detailed topographic mapping of the area was done. The map is based upon barometric determinations of altitude. Lake Quincy extended from approximately the Owen-Morgan county boundary on the east westward for a distance of about 12 miles. The northern limits of the lake are not so easily determined for it is partially obscured on the north by deposits of Wisconsin outwash over the Lake Quincy lake deposits. It may have extended somewhat north of the Early Wisconsin moraine (Shelbyville) which crosses Mill Creek near the village of Eminence in western Morgan County. Lacustrine deposits associated with Lake Quincy extend over an area covering between 40 and 50 square miles. It is probable that the lake at no one time covered all of this area. It seems likely that the eastern portion of the lake was the first to develop, and recession of the Illinoian ice front northwestward allowed an expansion of the lake to the west, but as this occurred it is probable that the lake shrank in size at the east. The reason for this conclusion will be pointed out when the outlets of the lake are discussed.

The lake plain which represents the former site of Lake Quincy is most typically developed between the altitudes of 755 to 770 feet but at the eastern and northern ends of the lake the floor of the lake plain rises up to altitudes between 785 and 790 feet. The higher altitudes here are due to inwash of materials from the Wisconsin drift which lies just north of the site of Lake Quincy. This Wisconsin outwash is especially noticeable in the area east of Cloverdale and south of Eminence.

From an altitude of about 790 feet at the east and north the lake

[5]The name Mill Creek will be used in this paper for the stream which flows southwestward through Hendricks, Putnam, Morgan, and Owen counties and joins Eel River near the southwest corner of Putnam County. In many of the older reports the term Eel River was sometimes applied to this stream, but the newer maps designate it as Mill Creek and apply the name Eel River to the stream into which Mill Creek flows. Eel River may be considered as beginning at the junction of Little and Big Walnut Creeks about four miles southwest of Greencastle. Eel River lies a few miles to the west of the area described in this paper.

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DEPARTMENT OF GEOLOGY
INDIANA UNIV
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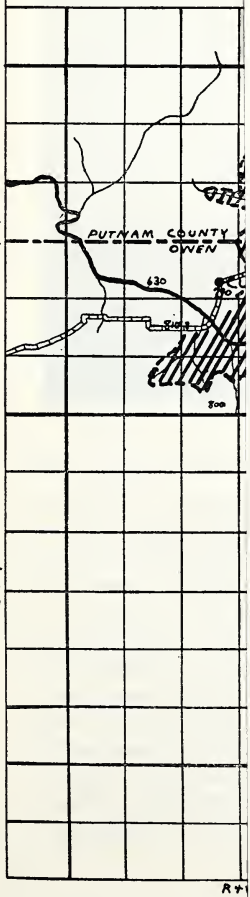

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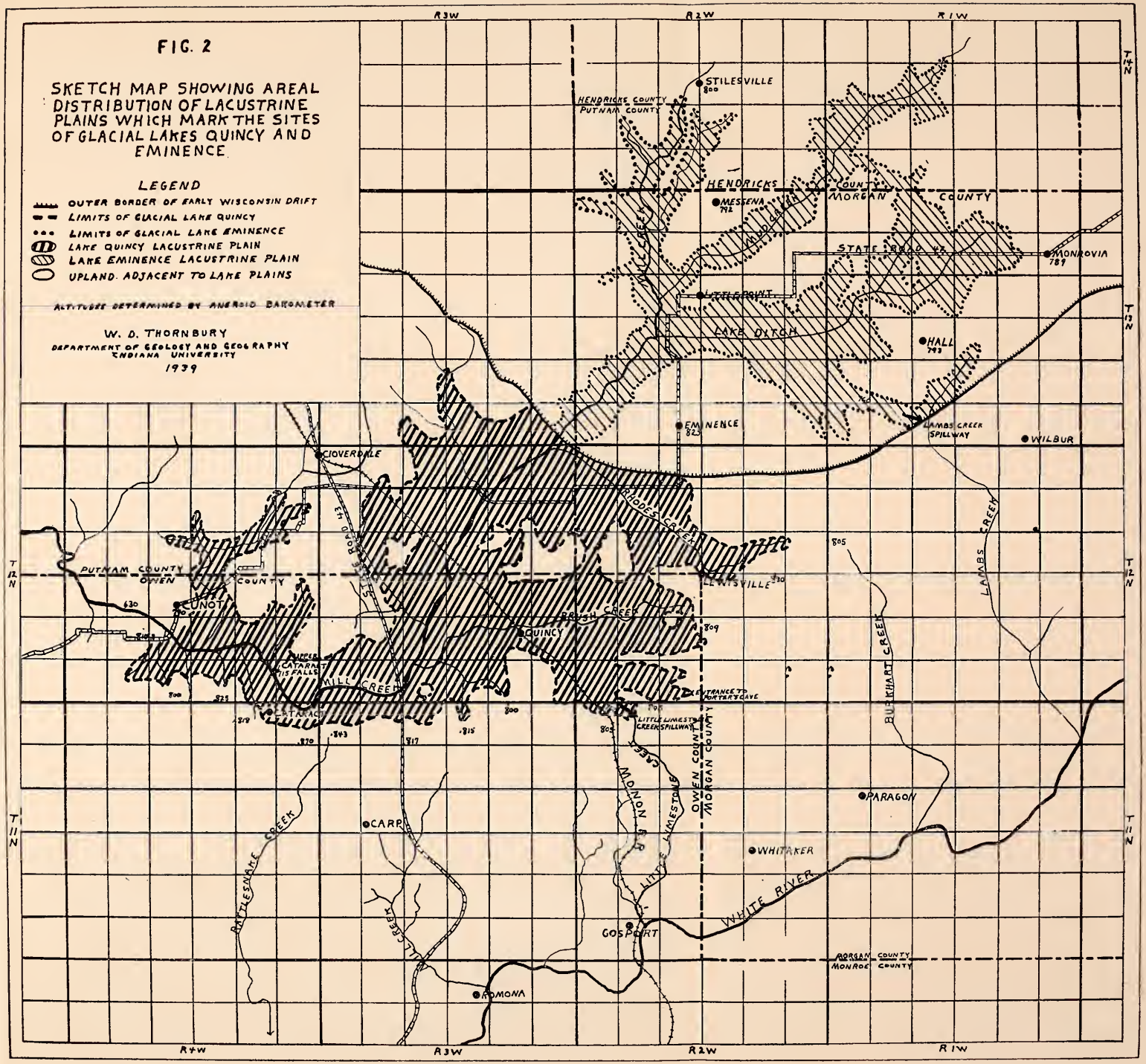
FIG. 2
SKETCH MAP SHOWING AREAL DISTRIBUTION OF LACUSTRINE PLAINS WHICH MARK THE SITES OF GLACIAL LAKES QUINCY AND EMINENCE
LEGEND
OUTER BORDER OF EARLY WISCONSIN DRIFT
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LIMITS OF GLACIAL LAKE EMINENCE
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W. D. THORNBURY
DEPARTMENT OF GEOLOGY AND GEOGRAPHY
INDIANA UNIVERSITY
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T13N
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T11N
STILESVILLE
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HENDRICKS COUNTY
PUTNAM COUNTY
HENDRICKS COUNTY
MORGAN COUNTY
MESSENA
792
MILL CREEK
MUD CREEK
STATE ROAD 42
MONROVIA
789
LITTLE POINT
LAKE DITCH
HALL
793
EMINENCE
823
LAMBS CREEK SPILLWAY
WILBUR
CLOVERDALE
RHODES CREEK
LAMBS CREEK
PUTNAM COUNTY
OWEN COUNTY
OWEN
805
LEWISVILLE
830
UNOT
630
BIG BRANCH CREEK
QUINCY
809
UPPER CATARACT FALLS
MILL CREEK
CATARACT
ENTRANCE TO CATARACT CAVE
LITTLE LIMESTONE CREEK SPILLWAY
BUCKHART CREEK
OWEN COUNTY
MORGAN COUNTY
MOONEY CREEK
PARAGON
CARP
WHITAKER
RATTLESNAKE CREEK
LITTLE LIMESTONE
WHITE RIVER
GOSPORT
MORGAN COUNTY
MONROE COUNTY
ROMONA

plain descends to the southwest to an altitude of about 755 feet at its westernmost limits. This is a slope of about 35 feet in a distance of about 15 miles, or a slope of slightly over 2 feet to the mile. The western half of the lacustrine plain has a much slighter gradient than the eastern part. In the section of the lake plain west of Quincy the slope is about one foot to the mile.

Considerable dissection of the Lake Quincy lacustrine plain has occurred in the lower part of the area. Mill Creek has cut out considerable amounts of the silts and clays deposited in the lake. At the point where State Road 43 crosses Mill Creek, Mill Creek has cut its valley down to an altitude of 720 feet, but the terraces which represent the level of the lake plain are at an altitude of 755 feet. However, extensive terraces composed of the lake deposits are preserved along the valley of Mill Creek. In the area above the village of Quincy, in northeastern Owen County, there is preserved an extensive area of the lacustrine plain which is as yet little dissected. A very good cross

Fig. 3. View of the lacustrine plain of Glacial Lake Quincy about one and one-half miles northeast of the village of Quincy in northeastern Owen County.

section of the lacustrine plain can be obtained by following the route of the Monon Railway from Cloverdale southeastward through Quincy to the southeastern limits of the plain about two and one-half miles southeast of Quincy.

At the northeast the lake plain abuts against the Early Wisconsin (Shelbyville) moraine, and at the east the lake deposits feather edge out against the sink-hole topography of the Mitchell plain. There is already some indication of encroachment of the southeastward drainage into White River upon the drainage of Mill Creek as numerous sink-holes may be seen at the eastern edge of the lake plain. As mentioned above, Addington has suggested that Lake Quincy may have had a partial subterranean outlet through Porter's Cave, but this does not seem likely to the writer for reasons which will be discussed later.

That the age of the Lake Quincy silts and clays is Illinoian, as suggested by Malott, and not Wisconsin, as suggested by Addington, is indicated by the depth to which the lake deposits have been leached of their calcium carbonate. Numerous determinations of the depth to carbonates were made both from exposures of these silts and from borings with a soil auger upon the floor of the lake plain. In all cases the lake silts were leached of their carbonates to depths between 12 and 15 feet. This clearly indicates an Illinoian rather than Wisconsin age for these silts as this depth of leaching corresponds very closely with the depth to carbonates in the Illinoian till of southern Indiana. Previous work by the writer[6] has shown that the Illinoian drift in southern Indiana is leached of its carbonates on an average to a depth of slightly over 13 feet, whereas the Early Wisconsin drift is leached of its carbonates to an average depth of about five and one-half feet. There is enough difference between the two that there can be no question as to the Illinoian age of the Lake Quincy deposits.

In Collett's discussion of the Lake Quincy region he suggested that Mill Creek formerly discharged into White River by way of Rattlesnake Creek. His suggested southward outlet of Lake Quincy was across Spangler's ridge, which runs east and west between the present course of Mill Creek and the headwaters of Rattlesnake Creek. Careful barometric determinations of the altitudes along the divide between Mill Creek drainage to the west and the various streams which flow southward into White River have indicated that there could not have been any outlet for Lake Quincy into Rattlesnake Creek. The altitudes along Spangler's ridge are given in Figure 2. The divide between Mill Creek and Rattlesnake Creek is everywhere well above 800 feet. An elevation of about 800 feet would seem to represent about the maximum altitude of the lake in its initial stage since the lake deposits are all below that elevation.

It does appear, however, that for a time Lake Quincy did have an outlet into White River, but it was not by way of Rattlesnake Creek as suggested by Collett, nor does it seem likely that it was by way of the underground route of Porter's Cave as suggested by Addington. It appears likely that during the initial stage of the development of Lake Quincy the lake covered roughly the area east of the village of Quincy. During this stage the lake discharged southeastward into Little Limestone Creek and thence into White River just east of Gosport. There is a very prominent col connecting the southeast end of the lake plain with Little Limestone Creek in the northwest part of Section 5 and the northeast part of Section 6, T. 11 N., R. 2 W. This col occurs at an altitude between 760 and 765 feet and unquestionably was the main, if not the only spillway through which Lake Quincy discharged its surplus waters to the southeast into White River. This spillway is designated as the Little Limestone Creek spillway in Figure 2, and its position is indicated by the arrow pointing toward Little Limestone Creek.

As the front of the Illinoian ice sheet receded to the west the lake expanded westward and eventually found an outlet at a lower altitude

[6]Thornbury, W. D., 1937. Glacial geology of southern and south-central Indiana. Pub. Indiana Cons. Dept., Div. Geol. P. 49.

to the west near the village of Cunot in northwestern Owen County. This outlet was probably some 10 feet lower than the eastern outlet as the level of the lake flat near Cunot is at an altitude of about 755 feet.

Lake Quincy must have persisted as a lake for a considerable period before lowering of its western outlet resulted in draining, for a considerable thickness of deposits was spread over the floor of the lake. No very accurate data as to the maximum thickness of the lake deposits were obtained, but probably at least 30 feet of silts were deposited in the lower end of the lake. Collett[7] gives the section shown in Table I from a well in Quincy.

TABLE I.—Section in Quincy Well

| | Ft. | In. |
|---|---|---|
| Black soil | 1 | 08 |
| White and gray clay with crawfish pipes, with little sand, no pebbles | 10 | 00 |
| Blue clay, with pebbles | 3 | 00 |
| Black mucky clay, with brush and plant remains | 3 | 00 |
| Hard pan and fine pebbles | 3 | 00 |
| Coarse gravel and boulders, depth unknown | 3 | 00 |
| Total | 23 | 08 |

Information obtained from the farmers in the region about Quincy indicated that they obtained their waters from wells sunk into the deposits over the floor of Lake Quincy. They usually obtained their water from sand and gravels at depths of about 24 feet. The depth to these gravels seemed to increase somewhat toward the west. How thick the gravels are cannot be stated as the wells only go a few feet into them. From the meager field exposures of the lake deposits it appears that the gravel deposits are largely in the eastern end of the lake and that the deposits in the western part of the lake plain are largely silts and clays. However, some sand may be seen around the edge of the lake deposits. One of the best exposures of the lake deposits is obtained where State Road 43 crosses Mill Creek. A portion of this exposure, showing the stratified nature of the deposits, is shown in Figure 4. Portions of the deposits are finely laminated, almost varved. The silts here rest upon glacial till which is slightly below the level of the road. The altitude of the base of the deposits is about 730 feet. This is about 25 feet below the level of the lake terrace here; so there seems to have been about 25 feet of filling in this particular locality.

Near the center of Section 32, T. 12 N., R. 4 W., there is an exposure of lake deposits about 30 feet in depth. It thus appears that 30 feet represents the minimum amount of filling in the lower end of the lake, and it seems likely that it was more than that farther east.

**Relation of Cataract Falls to Lake Quincy.**—Waterfalls are not very common along the streams of Indiana; so the occurrence of the two falls along Mill Creek suggests something unusual in the history of Mill Creek. While the falls would not attract much attention in some sections of the United States, in Indiana they are unusual, and the owner of the land on which they occur charges ten cents to see them.

[7]Collet, John, 1875. The geology of Owen County. Ann. Rept. Indiana Geol. Surv. 7:319.

Reference has already been made to the fact that the valley of Mill Creek above Cataract Falls is quite different in character from that portion of the valley below the falls. Mill Creek flows as a sluggish stream in that portion of its course which crosses the old lake plain. The present floodplain of Mill Creek at the northern end of the lake plain in southeastern Putnam County is at an elevation of 725 feet. In a stream distance of about 12 miles between this point and upper Cataract Falls, the river falls about ten feet. The upper Cataract Falls

Fig. 4. View of Lake Quincy lake deposits at the bridge over Mill Creek on State Road 43, showing stratified nature of the deposits.

are at an altitude of 715 feet. Below Cataract Falls, the valley of Mill Creek changes into a picturesque gorge, and in two falls of about 25 feet each and a series of rapids the stream falls about 90 feet in a distance of less than two miles. Where Mill Creek joins Eel River, the valley floor is at an altitude of about 620 feet. The gorge below the falls is in places about 200 feet deep, as the surrounding upland gets up to over 810 feet in elevation. The site of the upper falls is shown in

Figure 2. The lower falls is about a mile down the valley from the upper falls.

It is not known for certain what the exact course of Mill Creek was prior to the Illinoian glaciation, but it seems likely that it followed a southwesterly course in the same general direction that it now flows. There seems to be no convincing evidence to indicate that Mill Creek flowed to the south into White River as suggested by Collett. The elevations along Spangler's ridge would seem to preclude this possibility. Doubtless the pre-Illinoian valley was more deeply entrenched in the upland than the present valley is in the portion of its course above Cataract Falls. The advance of the Illinoian ice sheet from the northwest blocked the southwest drainage of Mill Creek and resulted in the formation of Lake Quincy as discussed above. For a time Lake Quincy drained out to the southeast into Little Limestone Creek and thence into White River, but after a time a lower outlet was found

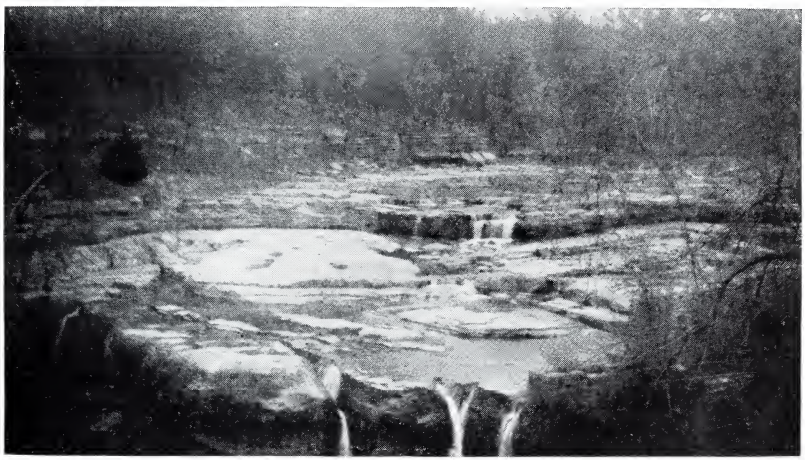

Fig. 5. View of the Upper Cataract Falls.

to the west near the village of Cunot. The lake existed for a long enough time for at least 30 feet of lake silts to accumulate in its basin. Cataract Falls developed at the time that the outlet of Lake Quincy changed from the southeast into Little Limestone Creek to the west into Eel River. Due to the filling which had taken place in Lake Quincy, the new outlet to the west developed at a considerable height above the old valley of Mill Creek, which had been buried under the lake deposits and discharged into the pre-Illinoian portion of the valley below Cataract Falls. After Lake Quincy had disappeared, either through filling of its basin with inwash or through lowering of its outlet, Mill Creek established its present course across the newly exposed lake plain. In the course of cutting out its valley in the lake deposits, Mill Creek encountered a buried ridge composed of the Mississippian limestones of the region, and this buried limestone ridge has pre-

served the falls in Mill Creek. The original site of the falls was probably about two miles farther down stream than the present site. In the time which has elapsed since the draining of Lake Quincy, Mill Creek has removed considerable amounts of the lake deposits, particularly in the western part of the lake plain, where the present valley of Mill Creek is cut from 30 to 40 feet below the upper level of the lake deposits.

## Glacial Lake Eminence

**Proposal of name.**—The name Lake Eminence is proposed for the second of the glacial lakes to be described in this paper. This name is taken from the village of Eminence in western Morgan County. There is no town located upon the lacustrine plain which marks the site of this lake, as is the case with Lake Quincy. The name of Lake Eminence was selected because the lake plain lies just north and east of the town of Eminence, and it also seemed appropriate because the lake was formed back of the Early Wisconsin (Shelbyville) moraine upon which the town of Eminence is located.

**Early references to Lake Eminence.** One of the earliest references to the lake area which is here designated as Lake Eminence is that of Brown[8], who, in discussing the geology of Morgan County, has the following to say regarding the effect of the glacial period upon Morgan County:

"The glacial period has left its footprints on the surface of Morgan county in a manner that time will hardly efface. Beginning at the Mill Fork of Eel River, a little north of Eminence, there is a valley about five miles wide, extending in a northeasterly direction; crossing the valley of White Lick Creek a short distance north of Mooresville, it passes into Marion county between West Newton and Friendswood, and thence to the valley of White River. From its western origin, to a point in section 1, range 1, township 13, near Monrovia, the valley gradually narrows to a width of about one mile. Originally, this section of the valley was a continuous lagoon, or swamp, locally known as 'The Lake'; but now it is drained westwardly into Eel River, by a public ditch, which has become quite a large creek. On the northern side, the depression of this valley seldom exceeds forty feet below the general level of the country, and the descent is commonly quite gradual. On the opposite side, the country rises from fifty to one hundred feet, and sometimes pretty abruptly. From the watershed near Monrovia, the drainage is eastward, by McCracken's Creek, to White Lick. . . . The topography west of White Lick indicates that this valley was the southern margin of the ice-field for a long time, and received the drainage floods from the disappearing glacier. South of this, I observed no gravel beds, or other evidence of rapid currents that mark a dissolving glacier."

Another reference to this laked region is that of Edmondson[9], who, in discussing the topography of Morgan County states:

"In the northwest part of the county is found a wide, low, inland valley, locally known as the 'Lakes.' From its outlet, into Eel River, west of Eminence, it extends in a northeasterly direction across Adams Township, touches the northwest corner of Gregg Township and reaches into Monroe Township to a point northwest of Monrovia. Here the wide ridge of rolling upland extending northward from the White River valley, several miles to the south, forms the divide between this and the level country

[8]Brown, R. T., 1883. Geology of Morgan County. Ann. Rept. Indiana Dept. Geol. and Nat. Hist. **13**:80.

[9]Edmondson, J. B., 1911. Soil survey of Morgan County. Ann. Rept. Indiana Dept. of Geol. and Nat. Res. **36**:84.

farther to the northeast. (Hence the statement by a former geologist (Brown), that the valley extends entirely across Morgan County and joins the White River valley in Marion County, is hardly possible.) The Lake region which was formerly covered with water the greater part of the year was slowly being reclaimed by the growth and decay of vegetation before the advent of the white man. By the use of large dredges and ditches this swamp has subsequently been converted into one of the richest farming regions in the State. . . .

"The lowest part of the valley extends east across the central part of Adams Township, nearly two miles south and approximately parallel to Mud Creek. This was the original outlet to the area, but the gradient being so slight it availed little as an outlet, becoming so filled in that drainage was stopped and the region was covered with runoff from the surrounding uplands a good part of the year. A few years ago, however, this old drainage course was reopened by a large dredge ditch and the drainage difficulties have been solved. The dredge or 'Lake Ditch,' begins in Monroe Township, northwest of Monrovia, and follows the lowest part of the valley in a southwesterly direction across the townships of Monroe, the extreme northwest corner of Gregg, and across the central part of Adams, emptying into Eel River, northwest of Eminence. The ditch is about twenty miles long and is estimated to drain 64,000 acres of extremely fertile soil. Emptying into it is a number of State ditches and many tile drains. In addition to this, the drainage facilities of the region have been much facilitated by the removal of an obstructing dam from Eel River and the straightening of its channel. By these means the water table in this area has been materially lowered although crops still suffer frequently from floods after excessive rains."

**Relation of Lake Eminence to Lake Quincy.**—The lacustrine area which is here designated as Lake Eminence lies just north and east from the Lake Quincy lake plain, and the two lake plains form a nearly continuous plain extending from northwestern Owen County into southern Hendricks County. They are developed at such similar elevations that it is not at all surprising that they should have been considered by the earlier geologists as part of the same lake plain. The Lake Eminence lake plain was so obviously the site of a rather recent lake that even the early settlers recognized this and referred to the area as pointed out above as "The Lake" or "The Lake Country." The field work done by the writer has convinced him, however, that the two lakes are of different age and even different origin. There are two convincing lines of evidence which indicate that Lake Eminence was formed much later than Lake Quincy. In the first place, the Lake Eminence lacustrine plain is much less dissected on the whole than that of Lake Quincy. Figure 6 is a view of the Lake Eminence plain taken about two miles northeast of the village of Eminence looking northwest across the floor of the lake flat. It has not been dissected at all throughout most of its extent. Only immediately adjacent to Mill Creek has any terracing occurred, where the present floodplain of Mill Creek has been cut from 10 to 15 feet below the original level of the lake bed. The Lake Quincy lake plain, on the other hand, has been noticeably dissected, particularly in its western portion, where Mill Creek has cut down about 30 to 35 feet into the lake silts and removed a considerable volume of the lake deposits. Only the upper end of Lake Quincy resembles the Lake Eminence plain.

More convincing evidence of the later age of Lake Eminence is found in comparing the depth of leaching in the deposits made in the two lakes. As was pointed out above, the Lake Quincy lake deposits have been leached of their carbonates to a depth of between 12 and 15

Fig. 6. View across the Lake Eminence lacustrine plain, about two miles northeast of Eminence.

feet, which indicates an Illinoian age for the lake. However, the deposits laid down in Lake Eminence have been leached only to a depth of between five and six feet on the average. This clearly indicates an Early Wisconsin age for Lake Eminence, as this depth of leaching corresponds closely with that found in the Early Wisconsin drift of the surrounding uplands. Thus, there is no escaping the conclusion that Lake Eminence was separate and distinct from Lake Quincy, which developed during the Wisconsin glacial epoch rather than during the Illinoian.

**Description and origin of Lake Eminence lacustrine plain.**--The Lake Eminence lake flat is extensively developed in northwestern Morgan, southeastern Putnam, and southwestern Hendricks counties. It covers a total area of approximately 30 square miles. The ponded condition extended up Mill Creek about to Stilesville in southwestern Hendricks County. The most extensive laked area was in the region between Monrovia and Eminence, east of Mill Creek.

The lake plain occurs at an altitude of 760 feet on the east and north and slopes southwestward to an altitude of about 750 feet where it abuts against the Shelbyville moraine. This gives it a downstream slope of about one foot to the mile. It will be noted that this corresponds very closely with the elevation at which the Lake Quincy plain is most extensively developed in its lower portion.

Figure 2 shows the relation of the Lake Eminence lacustrine plain to the Early Wisconsin or Shelbyville moraine upon which the village of Eminence is located and clearly shows that Lake Eminence was formed back of this moraine due to the ponding of the southwest drainage of Mill Creek by this moraine. The highest point on the Shelbyville moraine about one mile east of Eminence has an elevation of 840 feet.

Most of the moraine reaches up to 800 feet or higher. This moraine thus stands from 50 to 90 feet above the lake plain to the north of it. A considerable upland tract which was not covered by the lake lies in the area between Mud Creek and the Lake Ditch. Most of this upland tract lies below 800 feet in altitude.

One break in the upland which lies south of Lake Eminence is found in the south half of Section 29 and the north half of Section 32, T. 13 N., R. 1 W., about one and one-half miles southwest of the village of Hall. Here a col at an altitude of 760 feet may be seen. It appears likely that this col acted as a spillway for the waters of Lake Eminence into Lambs Creek and thence into White River during the early stages of its existence. The lake probably drained out through this route until the morainal dam across Mill Creek was cut lower than the outlet to the southeast, after which Lake Eminence established its outlet to the southwest through Mill Creek.

On the whole, the deposits in Lake Eminence are somewhat more coarse than those in Lake Quincy. Not many good exposures of these deposits are available, due to the undissected nature of the plain, but where they may be seen, as along the Lake Ditch, they exhibit large amounts of sand and gravel and very little of the finer silts and clays which are so abundant in the Lake Quincy region.

## Summary

The existence of an extensive area of lacustrine flats in portions of Owen, Morgan, Putnam, and Hendricks counties was recognized by early geologists, but most of the early observers assumed that the lake plain was all developed as part of one lake. The results of the present study indicate that there were two lakes developed in the region, one during the Illinoian glacial epoch and the other during the Wisconsin glacial epoch.

The name Lake Quincy has been given to that portion of the laked region which represents the site of the Illinoian lake. It developed as a pro-morainal or marginal lake around the border of the Illinoian ice sheet and was the result of the ponding of the upper portion of Mill Creek's drainage. During the early stages of its existence it discharged through a spillway into Little Limestone Creek and thence into White River near Gosport. Later in its history a lower outlet was developed at the west into Eel River. The lacustrine plain which marks the site of Lake Quincy covers between 40 and 50 square miles and is most typically developed at elevation between 755 and 770, but at the east the lake plain rises up to as high as 790 feet. There is no evidence to support the idea that Mill Creek prior to the Illinoian glaciation discharged through the present route of Rattlesnake Creek into White River, but it appears to have had a southwesterly course somewhat similar to its present course. Cataract Falls developed at the lower end of Lake Quincy where the post-Illinoian Mill Creek discharged into that portion of its pre-Illinoian course which had not been ponded. The falls have been preserved due to the fact that Mill Creek in excavating the lake silts in the lower part of the lake plain encountered a buried ridge or spur underlain by limestone. The Illinoian age of Lake Quincy is

indicated by the fact that the silts and clays deposited in it have been leached of their carbonates to depths of 12 to 15 feet, an amount of leaching comparable with that found in the Illinoian drift of the nearby uplands.

The name Lake Eminence has been given to the lake which developed just north of the site of Lake Quincy and back of the outer Early Wisconsin moraine which runs through the village of Eminence in western Morgan County. The lacustrine plain which marks its position is typically developed at an elevation around 760 feet, which is so nearly the same elevation as the Lake Quincy plain that it was thought to be a part of the Lake Quincy plain. The younger age of Lake Eminence is indicated by the fact that the lake deposits of this lake are leached to depths of only five to six feet. This depth of leaching corresponds closely with the depth of leaching in the Early Wisconsin drift and indicates that Lake Eminence was developed during the Wisconsin glacial epoch. The slighter amount of dissection of the Lake Eminence plain as compared with that of the Lake Quincy plain also indicates a younger age. It appears that Lake Eminence, during the early stages of its development, drained out to the south through a spillway into Lambs Creek and thence into White River; but it later developed a western outlet, and now the drainage of the lacustrine plain goes to the southwest through Mill Creek. The Lake Eminence plain covers an area of about 30 square miles and represents one of the most fertile soil regions in Morgan County.

# Heavy Mineral Assemblages from Upper Cambrian Formations as Exposed at Coon Valley and Victory, Wisconsin

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## Introduction

The heavy mineral assemblages here described were extracted from specimens collected by Gilbert O. Raasch and the writer while Raasch was preparing a paper on the Croixian Series in Wisconsin, which was later incorporated in the Kansas Geological Society Guidebook for 1935. The section is a composite of two sections located in the Stoddard Quadrangle just south of La Crosse, Wisconsin. Formations exposed at Coon Valley, 14 miles southeast of La Crosse on U. S. Highway 14,[1] include the entire Galesville member of the Dresbach formation and the Ironton member of the Franconia formation through an almost continuously exposed thickness of 100 feet. Formations exposed in a ravine in the Mississippi River bluff 1½ miles north of Victory, Vernon County, Wisconsin, and about 20 miles south of La Crosse[2] include the Fronconia formation with the exception of the lower portion of the Ironton member, the Trempeleau formation, and the lower part of the Oneota Dolomite, and another almost continuously exposed thickness of 340 feet.

The relative age and sequence of the rocks exposed in the Coon Valley-Victory section are as follows (4).

| | Thickness feet |
|---|---|
| Victory | |
| Ordovician | |
| Beekmantownian series | |
| Prairie du Chien formation | |
| Oneota Dolomite—lower 24 feet | 24.0 |
| Cambrian | |
| Croxian series | |
| Trempeleau formation—172.8 feet | |
| Madison member | 19.5 |
| Jordan member | 109.3 |
| Lodi member | 29.4 |
| St. Lawrence member | 14.6 |
| Franconia formation—182.1 feet | |
| Bad Axe member | 24.1 |
| Hudson member | 83.0 |
| Goodenough member | 28.5 |
| Coon Valley | |
| Ironton member | 46.5 |
| Dresbach formation—37.2 feet | |
| Galesville member | 37.2 |
| Total thickness | 416.1 |

[1]Exact location: Cliff rising above County Highway T in northwest part of Coon Vernon County, Wisconsin; SW¼, NE¼, Sec. 21, T. 12 N., R. 7 W.

[2]Exact location: Ravine in Mississippi River bluff 1½ miles north of Victory. Vernon County, Wisconsin; SW¼, NE¼, Sec. 21, T. 12 N., R. 7 W.

The purpose of this study is to bring another check to bear upon the boundaries between upper Cambrian formations and their members. To date, these formations have been separated on the basis of paleontology and the megascopic characteristics of the sedimentary rocks. It is hoped that this study of the heavy mineral assemblages will aid in the location of their boundaries.

No heavy mineral studies comparable to this have been made in the region. Earlier work has always dealt with the horizontal and vertical distribution of heavy mineral assemblages within a single formation. Thus, Wilgus (5) has published the results of studies of heavy minerals in the Galesville member of the Dresbach formation in southern Wisconsin. He finds zircon generally dominant with minor amounts of tourmaline and titanium minerals. Garnet is rare or absent except to the west where the member is very thin.

Pentland (2) studied the heavy minerals of the Franconia formation in a triangular area in southwestern Wisconsin, whose approximate apices are Madison, La Crosse, and Prairie du Chien. He found garnet dominant, high tourmaline, and low zircon but made no mention of ilmenite and its alteration products.

Ockerman (1) indicates in his studies of heavy minerals in the Trempeleau formation that garnet is strongly dominant, particularly in the Jordan member.

The writer wishes to acknowledge his indebtedness to Mr. Gilbert O. Raasch, one-time curator of the museum in the Geology Department at the University of Wisconsin, who measured the sections and collected the material for the heavy mineral study. The writer also thanks members of the Geology Departments at the University of Missouri and DePauw University for aid in the preparation of this paper.

**Preparation of materials.**—Because the strata in the Coon Valley and Victory sections are usually well consolidated, the cementing material being calcareous or dolomitic, it was necessary to remove the cement with hydrochloric acid. The residues were sieved through Tyler screens. Fractions with diameters greater than 1/16 mm. were immersed in bromoform with a specific gravity equal to that of dolomite (2.9). No record was made of the ratio of the weight of the heavy minerals to the weight of the total sample. The amount of heavy minerals found varied extremely from specimen to specimen but was generally highest in the highly glauconitic green sands of the Franconia formation. After separation, the heavy mineral assemblages were mounted on slides with Canada balsam, either entire or after splitting with a Jones microsplitter, and were thus made ready for microscopic examination.

**Heavy minerals.**—The important minerals present in the assemblages studied are: garnet, tourmaline, ilmenite, zircon, leucoxene, anatase, rutile, pyrite, limonite, and a few possible grains of pyroxene.

All garnet grains are characterized by a rough, etched surface and are usually colorless to light pink with occasional red grains.

Tourmaline grains are well rounded, show the usual good absorption, and are dominantly tints of brown or green with a few blue and violet grains. Several opaque tourmaline grains are present.

Ilmenite occurs as well rounded opaque grains which show a coating of gray or brownish-gray leucoxene in reflected light. These grains may often be entirely altered to leucoxene but in that case are almost pure white in reflected light.

Zircon is usually colorless, clear, and rounded enough to eliminate terminal faces but not enough to eliminate the prismatic elongation. Many zircon grains show zoning. An attempt to use zoning as a diagnostic feature of the zircon within a formation produced no results because there is just as great variation in the number of zoned zircon grains from bed to bed in one formation as there is from formation to formation.

Leucoxene and anatase usually occur together, the anatase apparently developing as an alteration product of the leucoxene or along with it and both of them derived from the ilmenite. Leucoxene is generally spongy, may occur in well rounded grains or in irregular masses, has a light gray to white appearance in reflected light, and is at times tinted yellowish-brown by limonite. Anatase usually occurs as well developed, tabular crystals, attached to grains of leucoxene, which show extreme dispersion with nicols crossed. The crystals are usually perfectly developed, indicating that they are authigenic.

Rutile occurs in very small amounts as rounded or somewhat prismatic grains of extremely high relief which are brown or reddish-brown in color and may show striations parallel to the elongation.

Pyrite ordinarily occurs as small, well developed octahedrons or as irregular, granular masses. It is abundant to the point of flooding the heavy mineral assemblages in the more shaly portions of the section and is present to some degree in the more dolomitic or calcareous portions. It is often highly altered to limonite.

Limonite is the most abundant iron oxide encountered. It occurs in extremely irregular opaque to semi-translucent grains which appear brown or yellowish-brown in reflected light. One or two well rounded grains, appearing steel blue in reflected light, may be magnetite but were included with the ilmenite because of the latter's great preponderance in numbers and because of the difficulty in making an exact differentiation.

Two or three grains of a moderate birefringence and relief, which were fairly well rounded, are found scattered throughout the section. They are thought to be pyroxene because of the lack of elongation and the dispersion shown. However, the data are meager since there were only a few grains, none of which showed good optic axis or bisectrix figures.

**Heavy mineral assemblages.**—The section studied shows the following assemblages of heavy minerals from the top of the section to the base.

The lower four feet of the Oneota dolomite of Ordovician age has the assemblage shown in figure 1. Garnet is outstanding, and tourmaline and zircon are present in small amounts.

The upper ten feet of the Madison member of the Trempeleau formation shows a dominance of tourmaline over zircon and garnet and considerable amounts of ilmenite and its alteration product, leucoxene.

Pyrite is present in very small amounts, probably due to its alteration to the large amount of iron oxide found in this portion of the Madison member (Fig. 2).

The lower eight feet of the Madison member has garnet again present in great abundance with tourmaline and zircon in much smaller amounts (Fig. 3). The Madison as a whole is a fine-grained, dolomitic sandstone 18.5 feet thick with a conglomeratic zone eight feet above its base.

The upper 93 feet of the Jordan member of the Trempeleau formation are consistently high in garnet, usually more than 75%, with tourmaline a very poor second and zircon in extremely small amounts (Fig. 4). This portion of the formation is made up of coarse-grained, poorly cemented sandstone.

The lower 18 feet of the Jordan member are quite shaly. Pyrite is the dominant mineral, varying from 41% to 92% of the heavies (Fig. 5). Garnet is second in importance, and all other minerals are present in extremely subordinate amounts.

The Lodi member of the Trempeleau formation is made up entirely of shale. Pyrite is the dominant heavy mineral, varying from 52% to 100% (Fig. 6). Garnet and other heavies are present in minor quantities.

The St. Lawrence or basal member of the Trempeleau formation is made up of dolomitic shale and sandstone and returns to the dominance of garnet in the heavy assemblages throughout the member, with pyrite a poor second and the appearance of appreciable amounts of ilmenite (Fig. 7).

The upper 51.5 feet of the Franconia formation, which include the Bad Axe member and the upper 28 feet of the Hudson member, are made up of shaly glauconitic sandstone and have a very characteristic assemblage of heavy minerals. Garnet varies from 38% to 69% and ilmenite from 14% to 45%; zircon is third in abundance and tourmaline fourth (Fig. 8).

The lower 54 feet of the Hudson member and the entire Goodenough member of the Franconia formation are made up of rocks similar to the upper portion of the formation but have an entirely different heavy mineral assemblage. Garnet is again the important mineral with zircon and tourmaline alternating in second position (Fig. 9).

The 1.5 feet of the Ironton member of the Franconia formation exposed in the section studied is a dirty, shaly sandstone. It has a heavy mineral assemblage exactly like that of the upper portion of the Franconia formation, the order of abundance being garnet, ilmenite, zircon, and tourmaline (Fig. 10).

## Conclusions

Changes in heavy mineral assemblages agree with formation and member boundaries set up on paleontologic and megascopic lithologic criteria except in the case of the three upper members of the Franconia formation. The upper 51.5 feet of this formation have the assemblage shown in figure 8. The lower 54 feet of the Hudson member and the entire Goodenough member have the assemblage shown in figure 9. Therefore, on the basis of heavy mineral assemblages, there would be three members in the Franconia instead of four.

The similarity of assemblages in the upper part of the Jordan and the lower part of the Madison may indicate considerable reworking of the Jordan sandstone before the source of the sedimentary materials changed. This condition is indicated in figures 2, 3, and 4.

Pentland's studies of the heavy mineral assemblages in the Franconia formation show no titanium minerals present. In the Victory section of the Franconia formation the upper 51 feet of the formation and the Ironton member show ilmenite second only to garnet and in amounts varying from 14% to 45%.

A study of heavy mineral assemblages extracted from deep well samples in Indiana might be an aid to more definite correlation of the Cambrian formations that are encountered.

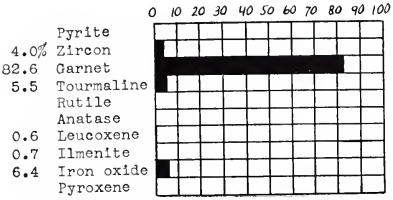


Fig. 1. Oneota Dolomite, Victory, Wisconsin, lower 4 ft.

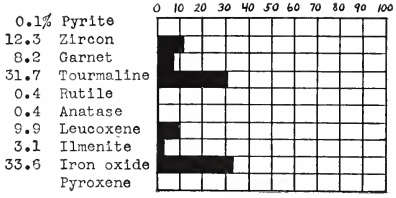


Fig. 2. Madison member of Trempeleau formation, Victory, Wisconsin, upper 10 ft.

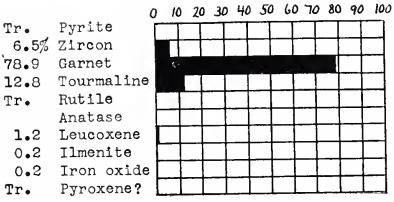


Fig. 3. Madison member of Trempeleau formation, Victory, Wisconsin, lower 8 ft.

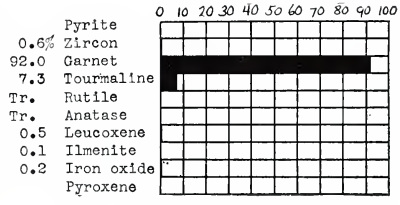


Fig. 4. Jordan member of Trempeleau formation, Victory, Wisconsin, 49 ft. to 74 ft. above bottom of Jordan.

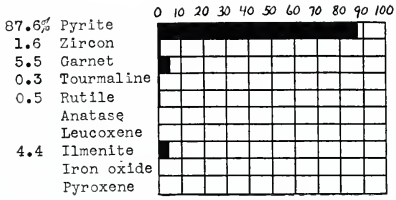


Fig. 5. Jordan member of Trempeleau formation, Victory, Wisconsin, 3 ft. to 10 ft. above bottom of Jordan.

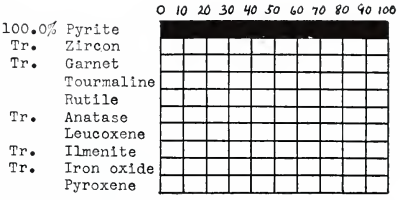


Fig. 6. Lodi member of Trempeleau formation, Victory, Wisconsin, lower 10 ft. of Lodi.

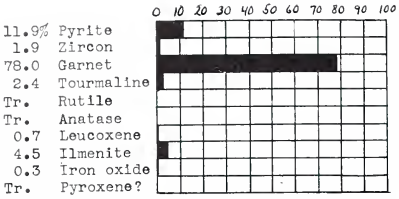


Fig. 7. St. Lawrence member of Trempeleau formation, Victory, Wisconsin, lower 5 ft. of St. Lawrence.

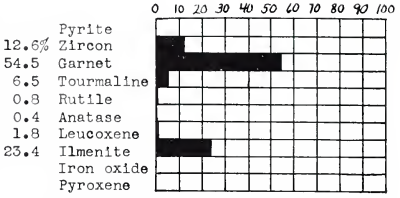


Fig. 8. Hudson member of Franconia formation, Victory, Wisconsin, 54 ft. to 65 ft. above bottom of Hudson.

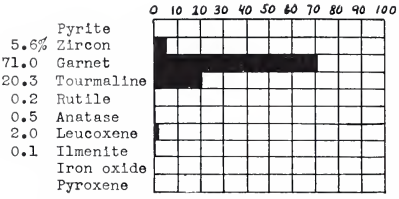


Fig. 9. Hudson member of Franconia formation, Victory, Wisconsin, 8 ft. to 12 ft. above bottom of Hudson.

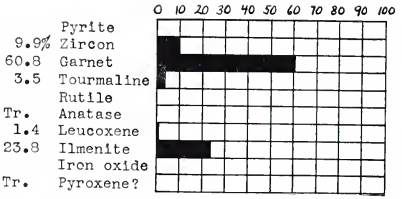


Fig. 10. Ironton member of Franconia formation, Victory, Wisconsin, upper 1.5 ft. of the Ironton.

## Bibliography

1. Ockerman, J. W., 1930. A petrographic study of the Madison and Jordan sandstones of southern Wisconsin. Journ. Geol. 38:346-353.

2. Pentland, Arthur, 1931. The heavy minerals of the Franconia and Mazomanie sandstones, Wisconsin. Journ. Sed. Petrol. 1:23-36.

3. Raasch, Gilbert O., 1935. Stratigraphy of the Cambrian system of the upper Mississippi Valley. Kansas Geol. Soc. Guidebk., 9th Ann. Field Conf. Pp. 302-315.

4. Twenhofel, Raasch, and Thwaites, 1935. Cambrian strata of Wisconsin. Bull. Geol. Soc. Amer. 44:1733.

5. Wilgus, Wallace L., 1933. Heavy minerals of the Dresbach sandstone of western Wisconsin. Journ. Sed. Petrol. 3:83-91.

# An Outline of the Classification of Indiana Soils

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At the last annual meeting of the Indiana Academy of Science the author presented a short paper having a related title, but that paper was devoted to a discussion of historical and philosophical aspects of soil classification and the relationship of kinds of soils to the data of other natural sciences. It contained very little specific descriptive material in regard to either the characteristics of soils or their systematic classification and did not contain a single name of a soil species, genus, or order. Moreover, only an abstract of the paper was published in the Proceedings of the Academy so that whatever repetition may exist in the content of the following paper will be new as far as publication in the Proceedings is concerned.

Obviously, the present paper is largely a new summarization of information which has been published to a considerable extent in the soils literature and is collected from scattered sources and presented here largely because of the interest in this subject expressed by persons who are not soil technicians.

The most complete summary of information about the soils of the United States, which has been published recently, is found in the 1938 Yearbook of the Department of Agriculture, entitled, "Soils and Men." That volume might better have been entitled "Men and Soils," since the first 750 pages contain relatively little soil information and only the last two or three hundred pages are used to cover the entire range of soil conditions for the whole United States. This paper will deal only with the soils of Indiana. In order to orient the material in reference to broader conditions, a few preliminary generalizations may be made.

In this discussion the soil is considered as a natural body which may be classified systematically, and the viewpoint is that the soil is a product of material modified by environmental forces under certain conditioning influences through varying periods of time. This might be stated like a formula

$$S = M \times F_e \times T$$

Some of the most important environmental forces are included under the term "climate," and from the soils standpoint, there is in Indiana a very limited range of climatic conditions which may be summed up as humid, temperate. There is nothing here like the arid climate which produces alkali soils, or the cold climate which produces tundra soils, or the hot, wet climate which produces lateritic soils as well as other regional soils groups as differentiated by climatic factors.

There is also in Indiana a limited range in the character of geological deposits from which soils have been formed; so it is impossible to have here many kinds of soil found in other parts of the world. In fact, soils identical to those in Indiana could be expected only within areas of a few nearby states where both rocks and climate are comparable. Since there is considerable similarity between the conditions in Indiana

and those in Ohio, Illinois, Michigan, and Kentucky, soil classification is an inter-state problem and has been carried on through cooperation of soil departments in other states as well as with the federal soil agencies which handle inter-state or national soil classification work. Of course, there is some degree of individuality and local independence in the work, and the statements made in this paper consist of the Indiana version of the classification of Indiana soils.

The characteristics of soils grade into each other even more than the characteristics of living creatures intergrade, and, just as some biological taxonomists state there is really no such thing as a "species," it can be said that there is no such thing as a "soil type" which is the unit of classification, and yet the idea which is set up for a soil type or species is a very useful guide in arrangement of information in an orderly manner. The general idea of a "soil type" is that it is a "kind" of soil having relatively uniform characteristics in its various individual areas. The character of a soil is expressed in its gross anatomy and its internal morphology as well as by microscopic or invisible attributes such as physical and chemical constants. The gross anatomy of an individual soil area or its conformation may be described in terms of the surface land form, the area outline or soil pattern, and the nature of the boundary between the true soil and the underlying geological foundation.

Land form specifications for soils may employ geological terms such as till plain, lake plain, moraine, kame, etc. These words are used with their customary meanings; no further explanation will be made here. Land form is also described in simpler terms such as flat, slope, hill, depression, etc., or by giving the percentage of slope as well as the length of slopes, variability in slope, or range of slope. Sometimes the land form is also given in land use adaptation terms.

The outlines of soil areas may be very characteristic of a type and are observed as to whether they are: sharp or indistinct, smooth and regular or irregular, large or small, linear or round, "background" or "detail." On an unlabeled soil map it is often easy to partially identify a soil by its shape alone.

The nature of the contact between a soil body and the geological foundation is much harder to observe than the other dimensions of gross form but can be determined as abrupt or gradual, regular or irregular, distinct or indistinct, etc.

The internal morphology of soils is exhibited in the principal layers or horizons. The main facts to note about the horizons are the number and arrangement in a given soil and thickness, color, texture, structure, consistency, and physical and chemical characteristics of each horizon. There is also the matter of the kind of transition or changes between horizons and the similarities in them.

While the horizons parallel to the land surface are the most conspicuous morphological units, they are, perhaps, not the most important distinctions which can be made. Just as skin, flesh, and bone, which are conspicuous and important layers in the leg of an animal, are perhaps less important in function than the blood vessels which pass through all of them, so the layers of soils may be less significant than the system

of cracks or channels which pass through several different soil layers and function there.

While soils in comparison with geological deposits are highly "organized" bodies, they are distinctly different from living organisms and may be thought of simply as the present product of dynamic, physical, and chemical interactions which are relatively slow in their changes so that the soil characteristics remain about the same for years at a time. Thus they may be classified on the basis of their present characteristics in spite of the fact that they formerly were considerably different and are undoubtedly changing in certain definite directions. At the present time, the classification of soils is based chiefly upon features and relationships which existed when the soil was at equilibrium with nature and these features remain and will persist in many respects in spite of the disturbed natural balance due to agricultural use of the soil. On the other hand, the practical classification does take into account some of the modifications due to agricultural use of the land, the recognition of erosion being the most outstanding instance of this kind. Even in the case of erosion, the scientific classification is based upon the nature of the soil profile which probably existed at a given point even though it has now been largely removed and is well on the way to becoming an entirely different soil in the same location.

Figure 1 shows in tabular form the principal characteristics of the most important soil types in Indiana. It will be noted that from a standpoint of features which can be observed in the surface form and the upper horizons of the soil profiles which reflect most strongly the environmental influences, all of the soils may be grouped under ten generalized concepts, which may be called "general soil profiles." These general profiles are arranged in orderly sequence according to gradations in characteristics, chiefly those dependent upon aeration, oxidation, and drainage. The degree and character of slope also changes systematically in this sequence with certain exceptions. The order of numbering on the columns is irregular because these numerals were established in connection with a somewhat similar table arranged in a different way and have come to have certain significance to soil technicians.

Column No. 6 includes some soils developed on some of the steepest slopes although it is possible to have soils of similar character on somewhat more gentle slopes. However, on the steep slopes the equilibrium between weathering and accumulation versus natural erosion is so much in favor of the latter that the surface material is relatively unmodified and there is little well oxidized soil material present in spite of the excessive surface drainage. In this respect this group of soils is an exception to the rule of arranging the groups in descending order of oxidation.

Column No. 5 includes soils which also are an exception to the general arrangement but for a different reason. They include the best oxidized soils of the whole list, due to the porous nature of the soil and underlying material which may consist of sands and gravels or stones. This well aerated and oxidized condition may occur in soils on topography ranging all the way from steeply sloping to flat land. In the flat land

it is, of course, necessary that the water table be low enough so that the underlying sands or gravel are dry, not saturated with moisture.

The soils in column No. 4 include those which are really the best drained, aerated, and oxidized group in the sequence of *comparable* soils, and their development correlates very closely with a degree of slope which insures rapid run-off of rainfall and good aeration most of the time.

Group No. 3 includes soils of poorer aeration and oxidation than in the case of group 4, due to somewhat less surface slope. There is also an imperfectly drained and aerated condition in the lower subsoil, due either to high water table or some sort of impervious soil or geological layer.

Group No. 2 includes soils with very gently sloping surface or soils which have a relatively high water table resulting in more or less mottled coloration, due to imperfect drainage conditions throughout the profiles.

Group No. 1 includes the flattest soils which are most poorly drained and aerated and most strongly reduced of all soils occupying *convex* land forms. That is to say, although they are frequently saturated, the rainfall has the opportunity to run *off* them rather than accumulate on the surface in more or less permanent ponds.

The soils of group No. 7 lie on land slopes practically as flat as those of group No. 1, but the land surface has a slightly depressed or saucer-shaped form which tended to collect and hold water which ran off higher land and thus kept the soil under more or less ponded conditions during its developmental period. This excess moisture, through stimulation of increased plant growth and preservation of plant residues, has contributed to the presence of a darker colored surface soil and mottled subsoil colors indicative of poor internal drainage. Some of these soils formerly may have been darker but are now leached because of improved natural drainage or greater age.

Group No. 8 includes soils where the conditions in group 7 have been stronger, more continuous, and more recent so that the surface soils are darker and deeper.

Group No. 9 includes soils developed under the highest degree and most permanent condition of ponding so the surface soils are usually quite dark and deep and subsoils are always very strongly reduced to light gray or drab colors. However, this group includes soils which are still dominantly composed of mineral matter rather than organic matter.

Group No. 10 includes soils which have formed under permanently wet conditions, and the accumulation of organic matter has been so great that the content of mineral matter in the soil has become relatively very low. In other words, the parent material of these soils consists of the remains of vegetation instead of being derived chiefly from mineral and geological deposits.

Soils to be found in any column correspond at least in principle with each other. That is to say, that they represent about the same relative degree of modification as judged by aeration, oxidation, and drainage. However, because of the fundamental differences of the nature of the different parent materials, it is impossible to expect exact corre-

spondence in appearance of all the soils within a given column. For instance, most sandstone soils found in column No. 4 are only reddish-yellow in the best oxidized condition, but some limestone soils placed in the same column may become quite reddish. Also the color of a soil developed under a forest cover is seldom as dark in the upper layers as that of practically the same soil developed under a cover of prairie grass; yet, in both cases the relative degree of oxidation may be practically the same and justify placing them in the same column.

The major groups indicated on the left hand side of the diagram may be regarded as corresponding somewhat to the time factor in soil formation. The group indicated by the letters DDD includes those in which the different layers of the soil profiles seem to be the result merely of deposition as in modern stream alluvium, which remains relatively unmodified and is considered very "young" both from a geological and soils standpoint. The group indicated by ABC includes soils which are usually from relatively young geological materials and are always youthful from the standpoint of soil formation. These letters may be interpreted as indicating that there is a more or less leached surface soil (A) with a subsoil (B) showing more or less accumulation of material leached or transported down from the surface and lying almost directly at depths usually of two to four feet upon relatively unmodified geological material (C). This generalization applies to the soils in columns No. 5, 4, 3, 2, and 1 but not to the soils in column No. 6 which might be called AC soils. This means that they have more or less leached and modified surfaces but no layers of accumulation. Instead, they lie almost directly upon the geological material. The generalization also does not apply very well to soils in columns No. 7, 8, 9 and certainly not to those in 10 because in these depressional soils there is relatively little tendency to develop an upper leached layer and a lower zone of accumulation. Instead, there are upper layers (H) darkened by humus and modified mineral subsoil layers (M) lying on some related or unrelated foundation of geological material (U).

The soils in the group indicated under the symbol ABYC are usually from geologically older material than those in the ABC group and are certainly older from the standpoint of soil development. Part of the greater depth of these profiles is taken care of by an extra layer labeled by the symbol Y which stands for the transition between the main subsoil horizon (B) and the unweathered geological material below. This generalization applies to the soils in columns No. 5, 4, 3, 2, and 1 although to some extent it also applies to those in 7, 8, and 9. The evidence of this greater maturity consists of deeper leaching and more thorough weathering of the soil material.

The soils in the group ABXYC correspond to some extent with those in the preceding general groups, but the depth of leaching is nearly doubled and the degree of weathering is much greater. As previously mentioned, the Y symbol stands for transition between the B and the C, but in this general group, especially in the soils of columns No. 1, 2, and 3, there is an especially modified layer which has been called "clay-pan," "hard-pan," "columnar horizon," etc. This is represented by the symbol X and seems to be the most strongly modified layer of

the entire profile. There is some evidence of an X layer in the soils of column No. 4, but it is doubtful whether it exists in those of column No. 5, and, of course, it does not exist at all in any soil placed in column No. 6 although it may be closely associated and derived from similar materials of the same geological age as the ABXYC soils. It should also be noted in this connection that in regions where ABXYC soils are found, types belonging in the 7 column are rare and types which could be put in 8, 9, or 10 are practically unknown.

The geological material from which soils are formed is one of the most important factors in soil genesis, but it is very difficult to put into precise language or to interpret accurately. It is customary to refer to groups of soils as sandstone soils, limestone soils, or Wisconsin till soils, etc., but such expressions may or may not actually characterize the soil in any significant fashion. Soils are described and identified on the basis of their own characteristics, and sometimes these do not seem to be very closely related to the rock from which the soil is supposed to have been derived. For instance, limestone soils supposedly derived from limestone consisting of 98% calcium carbonate are found to contain no calcium carbonate. It is also true that, although an Ordovician limestone and a Mississippian limestone may apparently give rise to two different soils, the soil differences may not be due to the facts which differentiated the two different geological formations but rather to the nature of the particular minerals which remain after weathering and are actually present in the soils. The word "till" in the field of soils has little meaning if it is defined as "ice-laid," but it is more significant if interpreted as meaning heterogeneous in particle size and lithological composition. It means little in soils to think of "loess" as something which may have been deposited by the wind, but it means a great deal as a material which is now very uniform in particle size and structure.

After the factors of climate, drainage, aeration, time, and parent materials have had their effects as indicated above, the factor of natural vegetation can bring about differences in soils which would otherwise be the same. The most conspicuous case of this kind is the difference between the prairie and timbered soils. In general, prairie soils are darker colored, but they also are less likely to form clay-pans than in corresponding timbered types.

This table, together with the general characteristics considered in its construction, takes care of practically all the soils to be found in the state of Indiana, allowing, of course, for the fact that there may be types of several different textures belonging to some of the soil series named in figure 1.

There are a few cases where additional factors must be taken into account in characterizing some of the minor soils of this region. For instance, there are some so-called alkali spots where there are concentrations of salts which justify classifying the soil as a different type.

All in all, the statement and table presented above should serve as a very good working basis for checking the most important characteristics of any of our soils and in identifying them as belonging to some particular series or at least as closely resembling that series. For instance, anyone, who finds a soil with a color and slope which could be

## SOIL SERIES OF INDIANA

| | MAJOR PROFILE | | VI | V | IV | III | II | I | VII | VIII | IX | X | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CHARACTERISTICS | % SLOPE | | 0-5 | 0-5 | 0-3 | 0-1 | 0-1 | 0-1 | 0-1 | 0-1 | 0-1 | 0-1 | |
| | ELEVATION ABOVE WATER TABLE | | 5'+ | 5'+ | 3-5 | 2-3 | 1-2 | 0-1 | 0'— | —1' | —2' | —3'+ | |
| | OVER FLOW | FREQUENCY | SELDOM | SELDOM | OCCASIONAL | | FREQUENT | MORE FREQUENT | MORE OR LESS FREQUENTLY PONDED AS WELL AS SUBJECT TO HEADWATER FLOODS | | | | |
| | | DURATION | SHORT | SHORT | SHORT | SHORT | LONGER | LONGER | | | | | |
| | | DEPTH | ONE TO TEN FEET OR MORE | | | | DEEPER | | DEEPEST | | | | |
| | COLOR | SURFACE | DARK | LIGHT | BROWN | GRAYISH BROWN | MOTTLED | LIGHT GRAY | GRAY | DARK GRAY | VERY DK. GRAY | BLACK | |
| | | SUBSURFACE | " | " | " | " | " | " | MOTTLED | GRAY | DARK GRAY | " | |
| | | SUBSOIL | LIGHT | " | LIGHT BROWN | MOTTLED | " | MOTTLED | | MOTTLED | LIGHT GRAY | DARK BROWN | |
| D | SWEET LOAMS | | | | GENESEE | FEL | | | | | WABASH | | |
| D | FROM LIMESTONE AND OHIO VALLEY | | | | HUNTINGTON | LINSIDE | | | | | | | |
| D | FROM SANDSTONE AND OLD DRIFT | | | | POPE | PHILO | STENDAL | ATKINS | | | | | |
| CHARACTERISTICS | % SLOPE | | 15-55+ | 0-25+ | 4-15 | 2-4 | 1-2 | 0-1 | 0-1 | 0-1 | 0-1 | 0-1 | |
| | SURFACE DRAINAGE | | EXCESSIVE | SLIGHT TO EXCESSIVE | GOOD | MODERATE | SLOW | VERY SLOW | INTERMITTENT | PONDED | | | |
| | INTERNAL DRAINAGE | | GOOD | EXCESSIVE | GOOD | MODERATE | " | " | VERY SLOW | | | NONE | |
| | COLOR | SURFACE | DARK GRAY BROWN | | | GRAYISH BROWN | BROWNISH GRAY | LIGHT GRAY | GRAY | DARK GRAY | VERY DK. GRAY | BLACK | |
| | | SUBSURFACE | VARIABLE | LIGHT BROWN | LIGHT BROWN | LIGHT BR. YELLOW | MOTTLED | " | LIGHT GRAY | GRAY | DARK GRAY | " | |
| | | UPPER SUBSOIL | " | REDDISH BROWN | YELLOWISH BROWN | BROWNISH YELLOW | " | " | MOTTLED GR.Y. & BR. | | GRAY & LIGHT GR. | " | |
| | | LOWER SUBSOIL | " | DK. REDDISH BROWN | GRAYISH BROWN | MOTTLED GR. & BR. | " | LIGHT MOTTLED | MOTTLED GR. & BR. | MOTTLED Y. GR. & BR. | MOTTLED LI. GR. & BR. | DARK BROWN | |
| A | HIGH LIME TILL | TIMBERED | HENNEPIN | | MIAMI | | CROSBY | BETHEL | | BROOKSTON | CLYDE | MUCK | |
| | | PRARIE | | | PARR | | | | | | | | |
| A | HIGH SHALE TILL | | | | ST. CLAIR | | NAPANEE | | | | PAULDING | | |
| A | TILL ON LIMESTONE | | | | MILTON | | RANDOLPH | | | MILLSDALE | | | |
| B | HIGH LIME GRAVEL | TIMBERED | RODMAN | FOX | MILL CREEK | | | | | WESTLAND | ABINGTON | | |
| B | | PRARIE | | WARSAW | | | | | | | | | H |
| B | LOW LIME GRAVEL | | | OSHTEMO | | | | | | BRADY | GILFORD | | |
| C | LOW LIME SAND | OLDER | | PLAINFIELD | | BERRIEN | | | | NEWTON | MAUMEE | MUCK | |
| C | | RECENT | BRIDGEMAN | CALUMET | | | | | | | DEMOTTE | | |
| C | LIMY LOAMS | TIMBERED | | | LUCAS | | HOMER | | | | | | |
| C | | PRARIE | | | JASPER | | | | | RENSSELAER | MAUMEE | | |
| C | HIGH LIME SILTS AND CLAYS | | | | MARKLAND | | MC. GARY | | ZIPP | MONTGOMARY | KINGS | | |
| A | HIGH LIME TILL | TIMBERED | | | RUSSELL | | | | | | | | |
| A | | PRARIE | | | CARRINGTON | DANA | | | | | | | |
| A | HIGH SHALE MEDIUM LIME TILL | | | | GALENA | | OTIS | | | | | | |
| B | LOW LIME HIGH SANDSTONE TILL | | | COLOMA | HILLSDALE | | | | | | | | M |
| B | SHALEY GRAVEL | TIMBERED | | TRACY | | HANNA | | | | | | | |
| B | | TRANSITION | | LYDECK | | ALIDA | ARDMORE | | | | | | |
| B | | PRARIE | | DOOR | | | | | | WESTLAND | ABINGTON | | |
| Y | HIGH LIME GRAVEL | TIMBERED | | DELPHI | | | HOMER | | | | | | |
| Y | | PRARIE | | WEA | | | | | | | | | |
| C | LOW LIME GRAVEL SANDS AND SILTS | | | MARTINSVILLE | | WHITTAKER | MAHALASVILLE | | | | | | |
| C | HIGH LIME TILL LOESS | | | | PRINCETON | IONA | AYRSHIRE | | | RAGSDALE | | | |
| C | LOW LIME TILL LOESS | | | PIKE | ALFORD | | IVA | | | | | | |
| A | LOESS ON SILTSTONE | | | | HOSMER | | COE | | | | | | U |
| A | HIGH LIME SHALEY TILL | | | | CINCINATTI | GIBSON | AVONBURG | CLERMONT | BLANCHESTER | | | | |
| A | LIMY SANDSTONE AND SHALE TILL | TIMBERED | | | CINCINATTI | GIBSON | VIGO | | | | | | |
| A | | PRARIE | | | | | CORY | | | | | | |
| B | TILL ON LIMESTONE | | | | GRAYFORD | | | | | | | | |
| X | TILL ON OIL SHALE | | | | JENNINGS | CANA | WHITCOMB | | | | | | |
| X | SHALEY LIMESTONE | | FAIRMOUNT | | SWITZERLAND | ALLENS | LAWRENCE | GUTHRIE | | | | | |
| Y | CHERTY LIMESTONE | | CORYDON | | FREDERICK | BEDFORD | LAWRENCE | GUTHRIE | BURGIN | | | | |
| Y | PURE LIMESTONE | | | | HAGERSTOWN | | | | | | | | |
| C | SANDSTONE SILTSTONE AND SHALE | | MUSKINGUM | | ZANESVILLE | TILSIT | JOHNSBURG | LICKDALE | | | | | |
| C | LOW LIME SILTS | | | BAINBRIDGE | OTWELL | HAUBSTADT | DUBOIS | ROBINSON | HARBISON | | | | |
| C | LOW LIME STREAM SILTS | | | | | | | | | | | | |
| C | OLD OHIO RIVER SILTS AND LOAMS | | | | WHEELING | SCIOTOVILLE | | GINAT | | CHILO | | | |

Fig. 1.

placed in column No. 4, with a well defined leached surface soil, a subsoil with clay accumulation, and with a lower subsoil consisting at a depth of about three feet of a heterogeneous material of different particle sizes and consisting of different minerals, would be justified in saying that this soil is "Miami" or at least "Miami-like."

The names in figure 1 are those of soil "series." A series is something like a genus and may include several "types," differing chiefly in texture of surface soil. A type is regarded as a species.

There is no general agreement as to higher categories in the classification. All of the soil series shown on a single line of the table are grouped as a "catena." Some of the series in any column may be considered a "family." Each complete column includes more or less related soils and the cross table grouping indicated by DDD, ABC, ABYC, and ABXYC each unites soils on a higher basis although no better name than these symbols is now available. Obviously there is still much to be done in perfecting soil classification.

# The Sun Spot Cycle and Temperature Departures at Indianapolis, Indiana, 1872-1936

Wallace T. Buckley, Indiana University

Since the discovery of the periodicity of sun spots by Heinrich Samuel Schwabe, who published his findings in 1843, there has accumulated an enormous volume of literature dealing with investigations of possible relationships between the solar cycle and terrestrial phenomena. Weather variations, climatic changes, plant growth, crop yields, floods, earth magnetism, and human health and behavior have been correlated with the sun spot cycle. The works of Stetson (1) and Clough (2) may be cited as examples of such studies.

The possible effect of sun spots on weather, particularly temperature, has been a popular field of investigation. These investigations seek to establish a definite periodicity in weather variations which will correspond with those of the sun spots. The conclusions of these studies are conflicting. The negative attitude may be illustrated by the following quotation (3): "It is certainly impressive to the thoughtful mind to realize that there is even a slight connection between solar and terrestrial phenomena but the delicacy of this connection is such that it still remains true that the study of meteorology is essentially the study of the earth's atmosphere as acted upon by a constant source of heat, the sun. None of these astrophysical studies should tempt the meteorologist to wander far from the study of the dynamics of the earth's atmosphere and the effect of the oceans and the continents that diversify the earth's surface." The following (4) illustrates the positive attitude. "The principal departures from normal climates which comprise weather are due primarily to a group of periodic variations of the sun's radiations rather than to terrestrial complexities, as has been generally supposed. Sun spots are associated with important modifications of weather not hitherto recognized."

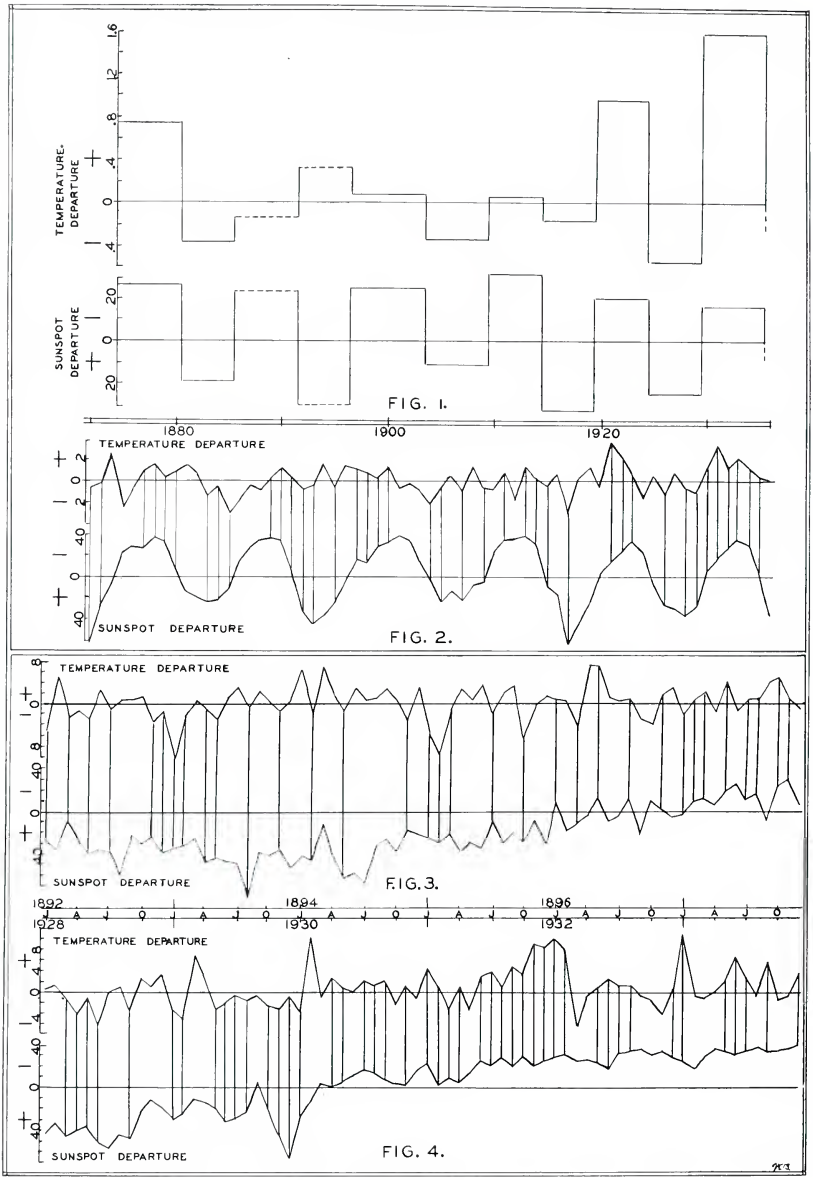
Among those meteorologists and astrophysicists who hold that there is a measurable relationship between sun spot activity and weather variations, there is disagreement as to the nature of the relationship. With regard to temperature, some believe the relationship to be inverse, *i.e.*, an increase in sun spot activity results in decreased temperatures, and a decrease in sunspot activity brings about an increase in temperature. This viewpoint can probably be traced to the works of Köppen and Mielke (5) and has had a more recent application in the work of Henry (6).

This paper investigates the relationships between temperatures for Indianapolis, Indiana, as recorded by the United States Weather Bureau (7) and the Wolf sun spot index numbers (8). These data are plotted to check the assumption that the solar and terrestrial relationship is inverse.

In figure 1 the sun spot index numbers are averaged for the epochs

in which the solar activity was above or below normal. The departures above or below normal are plotted along a base line which represents the average annual sun spot number.

Between 1875 and 1937 there were six epochs in which sun spot




Figs. 1-4.

activity was below average. The longest period of minimum sun spots, seven years, included the years 1897 to 1903. Two periods, 1910 to 1914 and 1920 to 1924, were but five years each. The epochs of maximum sun spots between 1875 and 1937 were five in number. One epoch, 1904 to 1909, lasted six years. The other four epochs had a length of five years each.

The temperatures plotted in figure 1 are the average of departures from normal for the years included in the epochs of maximum and minimum sun spot activity. For the years 1875 to 1880 the average temperature departure was above normal, and the sun spot activity was below normal. Thus, for this epoch an inverse agreement is established.

For the eleven epochs of maximum and minimum sun spot activity shown in figure 1, there is an inverse agreement between temperature and sun spot departures from normal in nine cases. The two exceptions occurred in the epochs of 1886 to 1891 and 1892 to 1896. This establishes, for Indianapolis temperature departures, an inverse agreement in about 82% of the sun spot epochs studied.

In figure 2 sun spot and temperature departures from average are plotted by years. According to the original assumption, a plus sun spot departure should be associated with a minus temperature departure, and a minus sun spot departure should be associated with a plus temperature departure. Where such agreement occurs in figure 2, vertical lines connect the points of agreement.

In the 65 years between 1872 and 1937, 40 years agreed inversely in temperature and sun spot departures. This is an agreement of about 62%.

It is possible that an increase or decrease in solar activity might affect temperature departures inversely but not sufficiently to bring them above or below average. Thus, there might be an agreement in trend which would not be represented by the vertical lines in figure 2. Such a situation is illustrated in the years 1875 to 1876. Agreement in trend is apparent in 37 of the 65 years charted. This is an agreement of about 60%.

Figure 3 and figure 4 represent sun spot and temperature departures from the monthly averages. They are sections from the chart covering the 780 months between 1872 and 1937. Figure 3 shows the 72 months in the period 1892 to 1897, and figure 4 the 72 months in the years 1928 to 1933. In figure 3 inverse agreement occurs in 34 of the months concerned for an agreement of about 47%. In figure 4 inverse agreement is found in 44 months, an agreement of about 62%.

For the full chart there is agreement for 396 of the 780 months considered. This is an agreement of 51% or only slightly better than might be expected from the operation of the law of chance. The highest agreement occurs in the years 1921 and 1929. Ten of the 12 months in each of these years had temperature departures varying inversely with the sun spot departures. The lowest agreement occurred in 1875 when only two of the 12 months were in agreement.

Agreement in trend between sun spot and temperature departures as revealed by the monthly chart shows that form of agreement in 378 of the 780 months or in about 49% of the cases considered.

Solar activity in any given month might be reflected in temperature departures not for that month but in some subsequent month. The possibility of a lag in agreement was investigated on the monthly chart. Allowing a time interval of one month, it was found that 370 of the 780 months considered agreed inversely for a percentage of about 48. Increasing the lag interval beyond one month did not consistently increase the percentage of agreement.

The following conclusions may be drawn from the above discussion:

1. Temperature departures from the average are most likely to agree inversely with sun spot departures when the period used is the epoch of maximum and minimum sun spot activity. Over a 62-year period at Indianapolis, which covered 11 epochs, there was an agreement of 82%.

2. With shorter time intervals, the year or the month, the agreement becomes less pronounced, that for the year being 62% and that for the month 51%. The monthly agreement is about what might be expected from the operation of the law of chance.

3. Agreement in trend seems to be less significant than the actual agreement in departure from the average.

4. There is no evidence that a lag interval of one month or more increases the percentage of agreement.

## Bibliography

1. Stetson, Harlan True, 1937. Sun spots and their effects, New York.

2. Clough, H. W., 1933. The 11-year sun spot period. Secular periods of solar activity and synchronous variations in terrestrial phenomena. U. S. Weather Bur., Monthly Weather Rev. **61**:99-108.

3. Abbe, Cleveland, 1901. Sun spots and meteorology. U. S. Weather Bur., Monthly Weather Rev. **29**:264.

4. Abbot, C. G., 1933. Sun spots and the weather. Smithsonian Misc. Coll. **87**:1.

5. Baur, Franz, 1925. The 11-year period of temperature in the northern hemisphere in relation to the 11-year sun spot cycle. U. S. Weather Bur., Monthly Weather Rev. **53**:204.

6. Henry, A. J., 1923. Sun spots and terrestrial temperature in the United States. U. S. Weather Bur., Monthly Weather Rev. **51**:243-249.

7. U. S. Weather Bur., Climatic Summary U. S. Sect. 67. P. 5.

8. U. S. Weather Bur., Monthly Weather Rev. **30**(1902):173 (and subsequent volumes).

# Weathering of Ferruginous Beds in the Pennsylvanian of Greene County, Indiana[1]

ROBERT R. SHROCK, Massachusetts Institute of Technology

The Pennsylvanian in Greene County, Indiana (and in adjoining counties as well), contains occasional thin, hard and tough, ferruginous layers composed largely of iron carbonate and fine silt with minor amounts of calcium carbonate and organic matter. The rock is unusually heavy because of the large amount of iron and breaks down readily under normal surface weathering. Iron carbonate is changed to limonite and is left in successive thin shells concentric to the unweathered kernel of original rock (Fig. 1); calcium carbonate, if present, is dissolved by percolating ground waters and carried away; and the fine silt and organic matter are probably removed as suspended material. Ultimately, much of the iron is released during continued weathering, and it finds its way into contiguous strata and adjacent stream deposits where it becomes both coloring matter and cement.

The weathering cycle begins with circulation of ground water through the jointed layer (Fig. 1) and ends when the original rock has been destroyed completely and its constituents deposited elsewhere. Almost any stage in the cycle may be seen in an extensive outcrop.

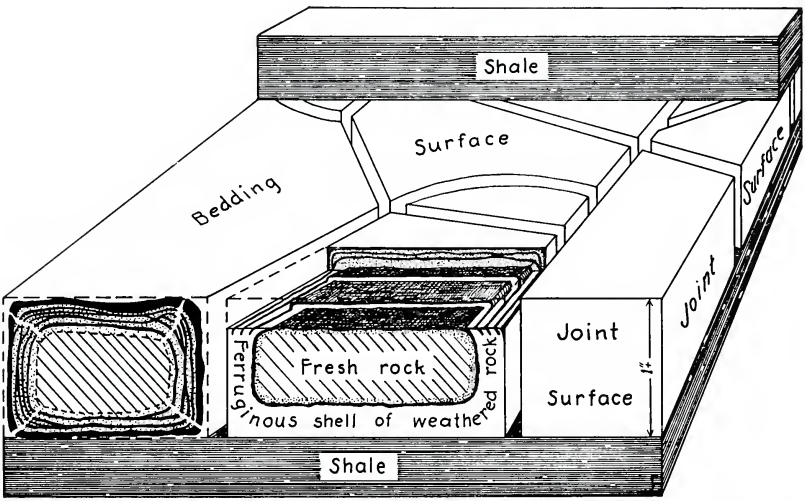



Fig. 1. Diagram showing how a jointed ironband weathers into polyhedra with rounded edges and successive concentric shells of limonite surrounding a core of fresh rock. Sketch based on exposures in a ravine in the N.W. ¼ Sec. 6, T. 6 N., R. 4 W., 2½ miles southeast of Bloomfield.

[1]Observations on which this discussion is based were made during field work for the Sun Oil Company, Philadelphia, in the summer of 1938. Permission to publish has kindly been granted by the Sun Oil Company.

The ferruginous sediment is believed to have been deposited in a quiet, shallow body of fresh water into which streams and wind were bringing the constituents from the surrounding land surface.

**Stratigraphic associations.**—The ferruginous rock occurs as thin bands ("ironbands") and zones of concretionary masses ("ironstones") at irregular intervals in the lower 300 feet of the Pennsylvanian in the eastern half of Greene County. The bands and concretionary zones lie in a sequence of sandstones, shales, and thin coal beds, as is apparent from the following sections:

Section in ravine in the N.W. ¼ Sec. 6, T. 6 N., R. 4 W., about 2½ miles southeast of Bloomfield, Greene County (in descending order).

| | | | |
|---|---|---|---|
| 9. | Blue shale weathering to gray clay | 3′ | 00″ |
| 8. | IRONBAND | | 01″ |
| 7. | Blue gritless shale breaking into chips and weathering to gray clay (mud) | 2′ | 06″ |
| 6. | IRONBAND (furnished specimens shown in Figs. 2 and 3) | | 01.5″ |
| 5. | Gritless blue shale | 1′ | 00″ |
| 4. | Iron-stained sandstone with small, kidney-like shale flakes | | 02″ |
| 3. | Black bituminous sandstone which is bedded, but is tough because of the strong bituminous cement | 1′ | 00″ |
| 2. | IRONBAND, which is well jointed and releases "boulders" on weathering | | 02″ |
| 1. | Blue, somewhat sandy shale (Section bottomed in ravine just below the exposure of ironband No. 2). | 8′ | 00″+ |

Section measured along a ravine in the N.W. ¼ Sec. 21, T. 7 N., R. 4 W., just south of Highway 54 and about 4 miles east of Bloomfield, Greene County (in descending order).

| | | | |
|---|---|---|---|
| 6. | Thin-bedded sandstone | 2′ | 00″ |
| 5. | Blue gritless shale | 4′ | 00″ |
| 4. | IRONBAND, well jointed | | 02″ |
| 3. | Coal | | 04″ |
| 2. | Underclay | | 04″ |
| 1. | Blue, gritless shale (Section bottomed in ravine at base of shale unit No. 1). | 4′ | 04″ |

**Physical and chemical nature of the ferruginous rock.**—The rock of the bands and concretionary masses is usually dark colored when freshly broken and is both hard and tough. When thoroughly weathered, it takes on a gray color and may be soft and porous or ashlike. The unusual weight of the rock is at once apparent when a specimen is lifted and indicates a large amount of iron. In the following list the specific gravity of fresh and weathered ferruginous rock is compared with that of several well-known rocks of southern Indiana.

Table of Comparative Specific Gravities

| | | |
|---|---|---|
| 1. | Fresh ironband rock, Greene County | 3.58 |
| 2. | Fresh ironstone, Greene County | 3.26 |
| 3. | Weathered ironstone, Greene County (of No. 1) | 3.02 |
| 4. | Limonitic shell of weathered band (of No. 1) | 2.90 |
| 5. | Pennsylvanian shale, northwest of Worthington | 2.47 |
| 6. | West Franklin limestone, Evansville | 2.70 |
| 7. | Lithographic St. Louis limestone, west of Bloomington | 2.65 |
| 8. | Beech Creek limestone, Owen County | 2.62 |
| 9. | Salem limestone | 2.48 |

Layers of the ferruginous rock are always well jointed (Fig. 1) and, as a consequence, are really thin pavements of small rhombic blocks. These blocks have many shapes and are as much as 16 inches in greatest dimension. They slump down over weathered shale slopes as the band breaks up and collect as "boulders" in the ravines below the outcrops of the ironbands. A number of them are shown in Fig. 2, and they will be mentioned again later.

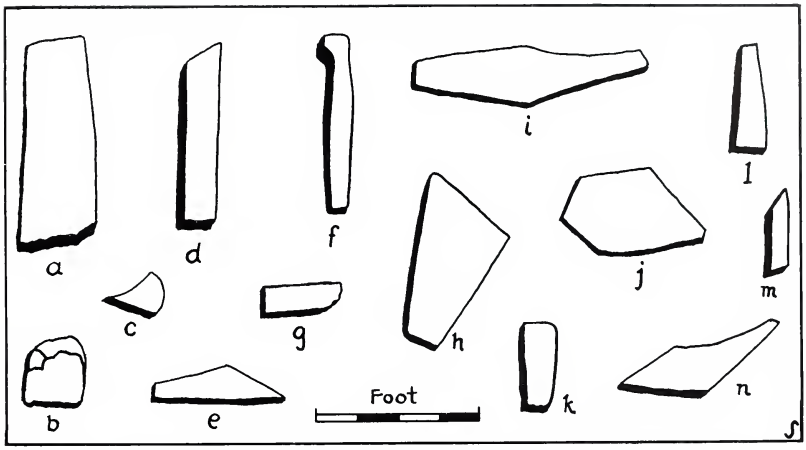



Fig. 2. Joint blocks released from a weathered ironband in a ravine in the N. W. ¼ Sec. 6, T. 6 N, R. 4 W., about 2½ miles southeast of Bloomfield. They owe their peculiar polyhedral shapes to joint planes and bedding or separation surfaces. Sketch based on a photograph.

Some of the shales associated with the ironbands contain large discoidal masses, several feet across, that have septarian structure in which the radial cracks are filled with calcite and small, irregular concretionary masses, which resemble sweet potatoes and are solid, dense, and tough, breaking conchoidally.

Chemically the ferruginous rock is quite variable in the percentages of the several constituents, and no single analysis conveys a true picture of this variation. The chief constituents, however, are iron carbonate (presumably ferrous carbonate), very fine silt (probably highly quartzose and containing some clay), calcium carbonate, and organic matter. Analyses listed by Logan[2] show that the iron averages slightly over 55% although the iron content probably varies considerably at different localities.

**Weathering of the layers.**—The weathering cycle affecting the ironbands begins when the first ground water circulates through the jointed layer and ends when the rock of the layer has been completely destroyed and its original materials scattered over the surrounding countryside. Since the layers usually lie between contiguous shale beds (Fig. 1) and appear to have been jointed almost from the time they were uplifted

[2]Logan, W. N., 1922. Handbook of Indiana geology. Pp. 761-762.

from the sea floor, they have always furnished excellent channels for circulating groundwater. This water, charged with carbon dioxide and oxygen, circulates through the openings in the ironband, attacking the blocks on the joint faces and bedding surfaces at first and later penetrating them by following cracks that develop along the edges (Fig. 1). In this manner weathering can continue until the entire block has been altered.

In the weathering, the ferrous carbonate is oxidized and hydrated to limonite, which remains as a thin shell around the unweathered core:

$$4FeCO_3 + O_2 + 3H_2O \longrightarrow 2Fe_2O_3 \cdot 3H_2O + 4\ CO_2$$

Any calcium carbonate present is changed into the bicarbonate and removed in solution:

$$4CaCO_3 + 4H_2O + 4CO_2 \longrightarrow 4Ca(HCO_3)_2$$

The silt or clay released during these reactions is carried out, probably as a colloid, or at least in a suspended state. Organic matter may go out in colloidal form, thereby increasing the efficacy of the water to dissolve calcium and ferrous carbonates; some may also act to stabilize any ferric oxide hydrosol that is being removed; and some may be trapped in the limonite shell.

Partial alteration, as shown in Fig. 1, produces rounded blocks composed of a core of unweathered rock surrounded by concentric shells of limonite (Fig. 3). Complete alteration produces rounded or polygonal hollow blocks (Fig. 4), which sometimes have small cores that act as rattles. In some instances, after a layer has been completely altered but before it has had a chance to disintegrate, the hollow blocks are cemented together by limonite into a continuous stratum with a mud-cracked appearance (Fig. 5). When such a layer is cracked open, however, one sees that the individual blocks are hollow, and the cavity

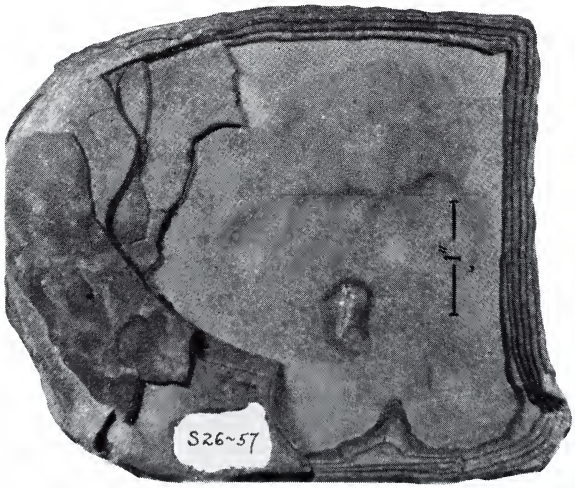



Fig. 3. A partly weathered joint block with rounded edges, showing the gray, unweathered core of fresh rock surrounded by concentric shells of dark, limonitic material which have exfoliated to a considerable degree on the upper side of the specimen. The bedding is in the plane of the page.


Fig. 4. Weathered joint block, now rounded into concretionary form, which has been completely altered with a hollow cavity remaining. The concentric shells are largely limonite that is firmly cemented.


Fig. 5. Weathered ironband in which the original joint blocks have been completely altered and then cemented by limonite into a continuous stratum. Most of the individual blocks are now hollow.

may be partly filled with yellow limonitic powder or it may contain a small fragment of original core, free to move about in the cavity as a rattle.

As the weathered ironband is uncovered and undercut by stream erosion and mass wasting, it disintegrates into the joint blocks (Fig. 2), which move downward to the drainage channels. When these leave the mother ledge, they are usually polyhedral slabs bounded by two smooth,

parallel surfaces—the separation or stratification planes—and a number of plane or curved joint surfaces (Fig. 2). The weaker of these, especially those which are hollow, will soon be broken up by impact. Some will lose the limonitic shell, also because of impact with other boulders, and the core of unweathered rock will then continue as a rounded "boulder" that may be mistaken easily for a limestone boulder. These may persist for long distances from the source. In some instances, only part of the concentrically laminated shell is lost; the rest remains with the core, and the resulting block has a concretionary appearance (Fig. 3).

Regardless of the nature of the ferruginous boulders, however, it seems very likely that sooner or later they will yield their iron to circulating ground waters, and this iron will be removed to become coloring matter and cement in other rocks and rock materials. Cases were observed where such iron had been carried downward into porous sandstones and had cemented them firmly; elsewhere, it had been deposited on stream gravels so that the pebbles and boulders not only were cemented together, conglomerate-like, but they also appeared to be composed of iron. A few taps from a hammer, however, usually sufficed to reveal this iron as a thin coating over the particles.

**Conditions of sedimentation.**—It may be postulated that the original ferruginous sediment was deposited as a fine silt and clay with a high iron content in a shallow body of fresh water to which it was being brought by streams and wind. Since the iron now exists in the unweathered rock as ferrous carbonate, it may be assumed that the sediment was deposited in a reducing environment. Moore and Maynard[3] have pointed out that most of the iron transported in river waters high in organic matter is probably carried as a ferric oxide hydrosol, which is stabilized by organic colloids. Some of the iron may also have been dissolved by carbonated ground waters and carried as ferrous carbonate.

If the iron was transported as a ferric oxide hydrosol, it would be co-precipitated together with the stabilizing organic colloids by the negatively charged muds. After deposition the oxide would then be reduced to ferrous carbonate within the mud. If, however, it were carried as ferrous carbonate originally, it would be precipitated directly in that form. This postulated sequence of events agrees best with the observed behavior of iron compounds in fresh water.[4]

During diagenesis, and perhaps to some extent later, the several constituents of the ferruginous deposit were cemented together into the tough rock which may be seen today in unweathered outcrops. The iron-bands, as a consequence, are much more resistant to weathering and erosion than the shales and other contiguous sediments with which they are associated. They became jointed early, and, by the time the rock had been elevated above the water table, channels were in existence for free circulation of groundwaters through the layer. Each block of the mosaic or pavement was subjected to weathering. Hence, each shows in miniature the history of the layer or band as a whole.

[3]Moore, E. S., and J. E. Maynard, 1929. Solution, transportation, and precipitation of iron and silica. Econ. Geol. 24:301.

[4]Hatch, F. H., R. H. Rastall, and M. Black, 1938. The petrology of the sedimentary rocks. George Allen and Unwin (3d ed. rev.). Pp. 147-149.

# Calcareous Incrustation Formed on Cascades at the Indiana State Soldiers and Sailors Monument, Indianapolis[1]

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Several years ago when the cascades at the base of the Soldiers and Sailors Monument were cleaned out thoroughly, a layer of stratified calcareous material, averaging about one inch (25 mm.) thick, was removed from the rounded edges of the six ledges (three in each cascade—see Fig. 1B) over which the water turbulently flows. We propose to describe this incrusting material and discuss some aspects of its formation.

**Occurrence of crust.**—The cascades on which the crust formed are located at the base of the monument on the east and west sides (Fig. 1D). Each cascade consists of three ledges, the upper of which is a shelf, and the two lower, terraces (Figs. 1A-B). Water is discharged by pumps at the outlet on the uppermost ledge, and it then cascades down across the second and third ledges to the basin whence it is recirculated.

According to Mr. Kurt Vonnegut the crust "formed only on the rounded edges (Fig. 1B) of the cascade ledges, on the vertical faces of the second and third drop, and heaviest of all immediately under the water supply outlet. On the edges of the cascades the crust was thin at the top and increasingly heavier downward to the point of drip (Fig. 1C). There was no sediment on the horizontal surfaces."[2] The crust was also somewhat thicker on the south sides of the cascades, possibly because the hotter afternoon sun accelerated evaporation and hence increased precipitation of calcium carbonate.

The incrustation formed in a period of about 20 years (1902?-1925?), during which time water from a well at the monument was used. About 1925—the exact time seems to be uncertain—the water supply in the well diminished to such an extent that it had to be augmented by water from the city mains, and within a few years thereafter city water was used exclusively and has continued to be used to the present. There was very little deposition of mineral matter after the change from well to city water because the latter is not nearly as "hard" as that from the monument well. Mr. C. K. Calvert, Chemical

[1]We are very grateful to Mr. Kurt Vonnegut for many favors, chiefly the drawings used in Figs. 1A-C and the photograph shown in Fig. 1D, and considerable detailed information about the occurrence of the incrustation. Much of this information was obtained through the kind cooperation of Mr. L. H. Coleman, Supervisor of the Indiana State Soldiers and Sailors Monument. Thanks are also due to Mr. F. C. Jordan, Secretary, Indianapolis Water Company, for information concerning the water consumption at various times and for other courtesies and Mr. C. K. Calvert, Chemical Engineer, for analyses furnished to Mr. Jordan. Finally, we are glad to acknowledge the assistance of Mr. J. Biscoe, Physics Department of the Massachusetts Institute of Technology, who made an X-ray powder analysis of the crustal material.

[2]Personal correspondence, January 18, 1938.

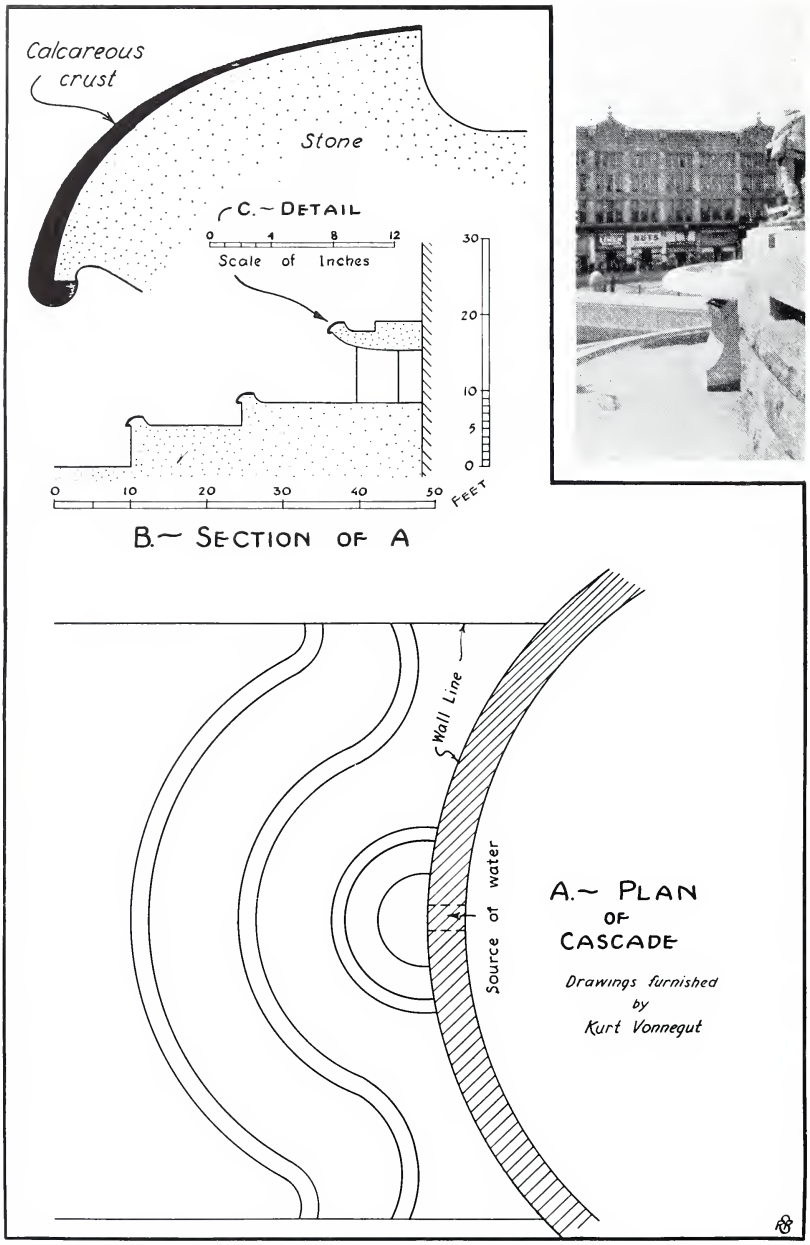


Fig. 1. Sketches and a view of west cascade at the Indiana State Soldiers and Sailors Monument, Indianapolis. (After K. Vonnegut).

Fig. 1D. View of the west cascade, looking northwest, showing the three ledges over which the water flows.

Engineer, kindly furnished the two analyses below, which show the solids in the water from the two sources, with the comment that the monument well "has been out of use for several years" and that "the water is much harder than the city supply and deposition (of calcium carbonate) from it will be at a higher rate, but the city water, under the conditions in the monument basin, will deposit lime."[3]

In the following analyses, Sample No. 1 was taken from the monument well on September 30, 1909, and Sample No. 2 is an average of city water for a seven-year period.

| | 1. Monument well (in parts per million) | 2. City water |
|---|---|---|
| Insoluble | 10.5 | 7.3 |
| Calcium (Ca) | 153.2 | 72.0 |
| Magnesium (Mg) | 46.8 | 13.0 |
| Sodium (Na) | | 27.0 |
| Sodium and Potassium chlorides | 124.6 | |
| Iron | 0.07 | 0.42 |
| Aluminum (A1) | | 0.31 |
| Sulphate | 192.7 | 58.0 |
| Chloride | 78.0 | 20.0 |
| Carbon dioxide ($CO_2$) | 16.0 | |
| Alkalinity | | 217.0 |
| Temporary hardness | 332.0 | |
| Permanent hardness | 268.0 | |
| Total hardness | | 290.0 |
| Total solids | 878.0 | 342.0 |

During the period when the incrusting deposit was made, it has been reported that the cascades usually operated from 9:00 A. M. to 5:00 P. M. during the warmer months (approximately April 15 to October 15) with a flow of about 4,000 gallons per minute for each cascade.

Apparently the repeated aeration and evaporation of the water, as it flowed turbulently over the cascades, and the consequent evolution of carbon dioxide from this as well as from release of pressure, caused precipitation of the calcium carbonate.

The basins were drained and cleaned bi-monthly during very hot weather and monthly during the remainder of the time the water was flowing.

**Nature of crust.**—The deposit formed a thin crust over the curved lip of each ledge, and this ranged from 5 to 40 mm. thick with greatest thickness at the point of drip on the ledge nearest the water source (Figs. 1A-C). Chemically, the deposit is rather pure calcium carbonate (95% ± 5%) with minor amounts of MgO, $R_2O_3$, and free C and a trace of sulphate. Mineralogically, it is calcite.

The crust exhibits wavy stratification, which is due largely to undulating films or thin zones and bands of black, carbonaceous matter (Fig. 2). These prominent black bands, numbering at least 16 or 17, are believed to represent the soot, dust, and other impurities which accumulated on the surface of the crust during the winter months when the water was not flowing. The stratification paralleled the surface of

[3]Personal correspondence, January 14, 1938.

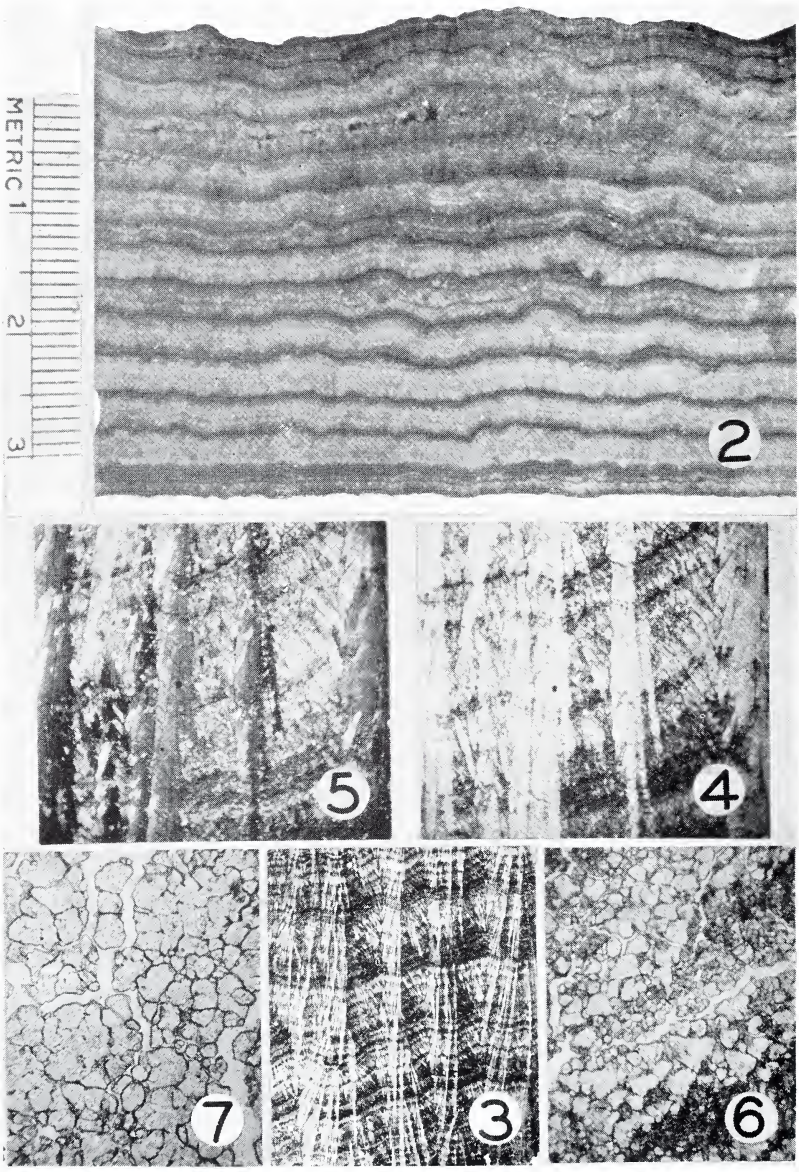


Fig. 2. Polished transverse section of the thickest part of the crust, showing the prominent black bands, between which are many thinner and fainter films of impurities. The more prominent bands are crowded in the lower part and incomplete in the upper.

Fig. 3. Photomicrograph of a small portion of the crust (X 2.5), showing several dark bands and bundles of transecting, acicular crystals of calcite.

Fig. 4. Photomicrograph of a section (X 10) transverse to the crust and parallel

the stone ledge on which it was deposited, and the acicular calcite crystals are disposed essentially at right angles to this surface and the stratification (Figs. 2, 3).

The general surface of the crust is like that of pebble-grained leather but is somewhat undulating with occasional prominent nodular protuberances. Former surfaces appear in transverse section (Fig. 2) as prominent wavy black bands, and the protuberances appear as areas of radial crystallization (Fig. 2).

The fainter and less regular dark films, numbering as many as 10 or 12 between the more prominent bands, may represent dust and other impurities related in some way to the cleaning of the cascades during the summer. The thickness of the material between the more prominent dark bands averages slightly over 2 mm., and this thickness, containing the 10 or 12 films just mentioned, is believed to represent one summer's deposit of calcium carbonate.

The crust is quite porous, especially in the upper third (Fig. 2), where cavities 1 mm. or more across appear and the banding is interrupted and incomplete. The upper part of this imperfect record possibly represents the deposits made during the period when city water was being used to augment the monument well.

The specific gravity of the crust is about 2.50 (2.44-2.59), which is slightly more than that of the Indiana (Salem) building stone (2.48) and slightly less than that of the lithographic St. Louis limestone (2.65).

**Formation of crust.**—The crust consists of calcite[4], but the conspicuously acicular structure strongly suggests that the calcium carbonate precipitated originally as aragonite and later recrystallized to the more stable calcite, retaining, however, the acicular character of the original aragonite. This suggestion is supported by the fact that the blade-like crystals of calcite cut across numerous prominent black bands, portions of which may or may not be preserved within the crystals (Figs. 3, 4). Apparently the original crystals—assumed here to have been aragonite—maintained their direction of growth through several summers with seasonal increments added in optical continuity. Then later, when the aragonite changed to calcite, the general crystal form was preserved, and in many instances portions of the numerous films and bands of impurities were preserved. In some cases, however, all traces of the original bands have been eliminated (Figs. 3, 4).

Under the microscope the crustal material is resolved into dark zones and thin bands through which are scattered bits of impurities,

[4]Mr. Jonathan Biscoe, Department of Physics of the Massachusetts Institute of Technology, kindly made an X-ray powder analysis of the material and found it to be calcite; the mineral was also identified microscopically.

with the elongated crystals, showing how the crystals transect several bands of impurities.

Fig. 5. Same as Fig. 4, with nicols crossed, showing the elongated character of the calcite crystals. The matrix is also calcite, with impurities.

Fig. 6. Photomicrograph of a section (X 10) parallel with the crustal surface and transverse to the crystals, showing the latter as rounded polygons which separate readily from each other.

Fig. 7. Portion of crust, X 20, showing same as Fig. 6.

the soot, dust, etc. already mentioned; these zones are transected by bundles of diverging or rectilinear, acicular crystals (Figs. 3, 5). In sections cutting the crystals transversely, the latter appear as rounded polygons and give uniaxial optic axis interference figures, showing that they are elongated parallel to the *c* axis (Figs. 6, 7). The material readily fractures parallel with the crystals which then separate as subprismatic needles with satiny luster.

The deposit obviously was derived from the well water, and it is possible to estimate roughly what fraction of the total calcium dissolved in the amount of water used was precipitated. From its dimensions the total mass of the deposit is estimated as five tons.

Assuming that the well water had the analysis reported (given earlier) and that approximately 3,500,000 gallons were used annually, then as now, it has been calculated that about 5% of the calcium in the water was deposited.

**Summary.**—This example of rather rapid deposition of calcium carbonate illustrates how that substance may be precipitated from ordinary ground water at normal surface temperatures and pressures. In this instance, the calcium carbonate precipitated from calcium-rich water bearing dissolved carbon dioxide and appreciable amounts of magnesium, sulphate, and chloride ions.

We believe that the carbonate originally precipitated as aragonite and later recrystallized to its present form, calcite. We recognize the possibility, however, that the deposit may have been calcite from the beginning.

The prominent dark bands in all probability represent annual accumulations of winter dirt, made when the cascades were not in operation. The maximum thickness of 40 mm. was deposited in about 3,600 eight-hour days in the 20 (more or less) summers of operation. This rate of deposition—approximately 2 mm. per summer—corresponds fairly well with the observed thickness of material between the more prominent, presumably winter-deposited dark zones. If deposition at this rate were continuous, about 12 mm. of calcium carbonate would be deposited annually.

# MATHEMATICS

Chairman: P. D. EDWARDS, Ball State Teachers College

Cora Hennel, Indiana University, was elected chairman of the section for 1940.

## ABSTRACTS

**A simple interpolation method for unsmooth curves.** C. LANCZOS, Purdue University.—If the values $y_0$, $y_1$, $y_2$, . . ., $y_n$ of a function $y = f(x)$, observed at the points $x = 0, 1, 2, 3, \ldots, n$, are so unsmooth that their difference table does not converge toward zero, the ordinary interpolation method by means of powers becomes illusory. In this case an expansion into a Fourier series will be more adapted to the nature of the problem. A definite solution of the interpolation problem may be obtained if the Fourier series has a sufficiently rapid convergence, *viz.*, if the number of coefficients practically present in the expansion does not exceed the number $n + 1$ of the given data. In order to satisfy this condition we at first construct the function $\phi(x) = f(x) - (\alpha + \beta x)$, where the constants $\alpha$ and $\beta$ are determined by the conditions that $\phi(0)$ and $\phi(n)$ shall be 0. We then define $\phi(-x) = -\phi(x)$ and expand $\phi(x)$ into a Fourier series between the limits $x = -n$ and $x = +n$. The construction guarantees the continuity of function and first derivative, and, therefore, sufficient convergence will be achieved for a satisfactory interpolation, provided that n is not too small. The resulting formula follows:

$$f(x) = \alpha + \beta x + \frac{\sin \pi x}{n} \sum_{k=-n}^{n} \frac{(-1)^k \Phi(k)}{\sin \frac{x-k}{n} \pi}$$

This formula is well adapted to easy numerical computation.

**Cubic hypersurfaces symmetric with respect to hyperplanes of a linear system.** D. R. SHREVE, Purdue University.—This is a generalization of a paper by Edgardo Ciani, "Sulle superficie algebriche simmetriche," giving a short account of cubic hypersurfaces symmetric with respect to hyperplanes of a pencil, of a net, and of a web, in projective space $S_r$. The configuration of generalized Eckardt points is considered in detail.

**New materials and equipment in mathematics.** INEZ MORRIS, Indiana State Teachers College.—A bibliography of equipment and books and magazine articles published during the past year, accompanied by an exhibit of these materials, was prepared. A discussion of these materials included reasons for the type of organization used in the bibliography, the need of teachers for familiarity with the newest materials in mathematics and in related fields, the values of such a bibliography to the busy teacher, an analysis of the relationship of the 1938-1939 texts

to current educational trends, and a brief review and evaluation of several outstanding publications.

**On the Dirichlet problem for the equation of the vibrating string.** RICHARD J. DUFFIN, Purdue University.—This paper gives a partial answer to the question of the solution being uniquely determined inside the contour if the value of a solution of the wave equation is given on a closed contour. It is shown that the answer hinges on whether or not a certain number defined by the particular contour under consideration is rational or irrational.

**Suggestions for the conduct of mathematics clubs.** MURET NUGENT, Indiana State Teachers College.—By title.

# The Integrating Factor $R = x^m y^n$ for Certain First Order Differential Equations

Will E. Edington, DePauw University

Consider a differential equation of the form

$$(h_1 x^{\alpha_1} y^{\beta_1} + k_1 x^{\gamma_1} y^{\delta_1})dx + (h_2 x^{\alpha_2} y^{\beta_1} + k_2 x^{\gamma_2} y^{\delta_2})dy = 0, \tag{1}$$

which is not exact. Suppose (1) may be made exact by means of the integrating factor $R = x^m y^n$. In order for $x^m y^n$ to be an integrating factor, certain linear relations must exist among the exponents of x and y, and, when these relations are satisfied, then certain other linear relations exist between m and n in which the h's and k's are coefficients. In general, the two equations in m and n are consistent, but under certain conditions these equations may be inconsistent. All these conditions are investigated in this study.

Assuming $x^m y^n$ to be an integrating factor, it follows that, if both members of (1) are multiplied by $x^m y^n$, the equation becomes exact, and then the partial derivative with respect to y of the coefficient of dx is equal to the partial derivative with respect to x of the coefficient of dy. Carrying through this multiplication, equating the partial derivatives, and factoring $x^{m-1}y^{n-1}$ out of all terms of the equation, one has

$$h_1(\beta_1+n)x^{\alpha_1+1}y^{\beta_1} + k_1(\delta_1+n)x^{\gamma_1+1}y^{\delta_1} = h_2(\alpha_2+m)x^{\alpha_2}y^{\beta_2+1} + k_2(\gamma_2+m)x^{\gamma_2}y^{\delta_2+1} \tag{2}$$

Since the members of (2) are identically equal, certain relations must exist among the exponents, and these appear to fall into two cases.

Case I. $\alpha_1+1=\alpha_2, \beta_1=\beta_2+1, \quad \gamma_1+1=\gamma_2, \delta_1=\delta_2+1,$

or $\alpha_1+\beta_1=\alpha_2+\beta_2, \quad \gamma_1+\delta_1=\gamma_2+\delta_2$ (3)

Then $h_1(\beta_1+n)=h_2(\alpha_2+m), \quad k_1(\delta_1+n)=k_2(\gamma_2+m),$

or $h_2m-h_1n=h_2\alpha_2-h_1\beta_1, \quad k_2m-k_1n=k_1\delta_1-k_2\gamma_2$ (4)

The equations (4) may be solved for m and n provided $h_1k_2 \pm h_2k_1$. (5)

Case II. $\alpha_1+1=\gamma_2, \beta_1=\delta_2+1, \quad \gamma_1+1=\alpha_2, \delta_1=\beta_2+1,$

or $\alpha_1+\beta_1=\gamma_2+\delta_2, \quad \alpha_2+\beta_2=\gamma_1+\delta_2$ (6)

Then $h_1(\beta_1+n)=k_2(\gamma_2+m), \quad k_1(\delta_1+n)=h_2(\alpha_2+m),$

or $k_2m-h_1n=h_1\beta_1-k_2\gamma_2, \quad h_2m-k_1n=k_1\delta_1-h_2\alpha_2$ (7)

The equations (7) may be solved for m and n provided $h_1h_2 \pm k_1k_2$. (8)

These two cases in reality are only one, for by interchanging the addends in the coefficient of dy and making the correction in signs, if necessary, Case I reduces to Case II, that is, abstractly there is only one case.

However, the first step to take in the solution of an equation of the form of (1) is to determine whether $h_1k_2=h_2k_1$ or $h_1h_2=k_1k_2$. If so, then no integrating factor of the form $x^m y^n$ may be determined. But then it is not necessary to determine such an integrating factor in order to find the solution of (1), for by making the substitution $y=vx$, the equation (1) reduces to a form whereby the variables may be separated, as will now be shown. The two cases will still be considered in

order to avoid confusion in notation although the work will be carried out in only the one case since the method is the same.

CASE I. Assume $h_1k_2=h_2k_1$. Let $y=vx$. Then $dy=v\,dx+x\,dv$. Substituting in (1), imposing conditions (3), collecting like terms, and factoring, one finally obtains $\left[(h_1+h_2)v\,dx+h_2x\,dv\right]\cdot\left[h_1x^{\alpha_1+\beta_1}v^{\beta_1}+k_1x^{\gamma_1+\delta_1}v^{\delta_1}\right]=0$,

whence $$(h_1+h_2)v\,dx+h_2x\,dv=0. \tag{9}$$

Solving, one has $x^{h_1+h_2}v^{h_2}=C$, or finally $x^{h_1}y^{h_2}=C$ as the solution of (1).

CASE II. Assume $h_1h_2=k_1k_2$. Imposing conditions (6) and carrying out the work as before, one gets exactly the same result except that $k_1$ takes the place of $h_1$ in the coefficient of $v\,dx$ so that the differential equation becomes

$$(k_1+h_2)v\,dx+h_2x\,dv=0, \tag{10}$$

and the solution of (1) is $x^{k_1}y^{h_2}=C$.

In both cases the algebraic factor $h_1x^{\alpha_1+\beta_1}v^{\beta_1}+k_1x^{\gamma_1+\delta_1}v^{\delta_1}$ is obtained. When v is replaced by y/x, this factor becomes $h_1x^{\alpha_1}y^{\beta_1}+k_1x^{\gamma_1}y^{\delta_1}$, which is the coefficient of dx in (1). Hence, the coefficient of dy may be readily rearranged so as to contain the coefficient of dx in (1), and the resulting differential equation may then be written down by inspection. Thus, any differential equation of the form (1) in which the conditions (3) and (5) or (6) and (8) are satisfied may be solved by means of an integrating factor of the form $x^my^n$, or it may be solved by inspection when condition (3) or (6) holds but condition (5) or (8) does not hold, respectively.

# PHYSICS

Chairman: R. B. Abbott, Purdue University

The sectional meeting on physics was attended by about 50 members and guests. Good interest was shown in the papers and discussion. A special feature was the exhibit of the Cenco Company of apparatus and supplies.

James F. Mackell, Indiana State Teachers College, was elected chairman of the section for 1940.

## ABSTRACTS

**Accoustical properties of wood for musical instruments.** R. B. Abbott and G. H. Purcell, Purdue University.—Specimens of wood in the form of rectangular bars 24 in. x ⅜ in. x ⅝ in. were tested for their density, elasticity, and internal resistance to motion. The effects of boiling the rods in water, ethyl alcohol, and turpentine and of coating them with oils, varnishes, paints, *etc.*, were observed. A method for separating the internal damping resistance from the air resistance was developed.

**The Indiana University cyclotron.** Franz N. D. Kurie, Indiana University.—The cyclotron now being constructed here is the second largest in the United States. The magnet, weighing 77 tons, is constructed of 0.08 to 0.15% carbon open-hearth steel. With the exception of the poles, all the steel is in the form of slabs 2 in. thick, bolted and welded together. The diameter of the pole tip is 45 in., that of the core is 54 in., allowing a final radius for the ions of about 19.5 in. The over-all dimensions of the magnet frame are 11 ft. x 9 ft. x 4.5 ft. The proportions of the magnet were determined by tests on a small scale model. Energizing coils were wound of ten tons of copper strip (1⅜ in. x ⅛ in.) in 24 pancakes. These coils were entirely homemade. They are to be cooled by water circulating through additional coils of ⅜-inch square copper tubing sandwiched between the conductor coils. At 50 KW the model tests indicate a field strength of about 17,000 oersteds for a gap of 6.25 in. This gap is composed of two shimming gaps of ⅝ in. each and a 5-inch vacuum gap. Preliminary decisions have been reached to feed the radio-frequency power to the dees through a vacuum resonant line. Tests on a full-sized model indicate the vacuum chamber can be made to resonate at about 24 m. This gives a probable output voltage for deuterons of 16 MV. The cylotron is housed in a room 75 ft. x 55 ft. which is semi-isolated from the new Physical Science Building now being constructed. It is planned to surround the instrument with a water wall in all directions as a protection from neutrons. The control room will be on a mezzanine about 40 ft. from the cyclotron.

**Focusing and resonance requirements for the Indiana University cyclotron.** Arnold F. Clark and Franz N. D. Kurie.—The electric and magnetic fields through which the ions pass in being accelerated in a

cyclotron must satisfy two conditions. One of these is that the angular velocity of the ion must keep the ion in step with the oscillating electrical field, within certain limits. The second condition is that the ions be as well focused as possible in order that the maximum intensity be obtained. In order to facilitate design, these conditions were investigated with models. A two dimensional model of the dees in an electrolyte ray was used to find the best geometry for electric focusing. For dees 3 in. high a separation of 1.5 in. was found to be optimum. Using a twelfth scale model of the magnet, the radial gradient (focusing component) of the magnetic field was measured by two small sensitive search coils bucking each other. Various iron shims were used to determine, to a first approximation, the corrections to the large magnet which will have to be made in order to satisfy both the focusing and relativity resonance requirements for 16 MV deuterons.

**The relation between the emission of beta and gamma rays in radioactive substances.** A. C. G. MITCHELL, L. M. LANGER, and P. W. MCDANIEL, Indiana University.—The relation between the emission of beta and gamma rays has been studied by measuring coincidences between beta and gamma rays with the help of a coincidence amplifier. The apparatus has a time constant of $0.56 \times 10^{-7}$ min. The radiations from $In^{116}$ (54 min.), $Mn^{56}$ (2.5 hr.) and $Na^{24}$ (14.8 hr.) have been investigated. In all of the above cases, the method shows that the product nucleus has been left in an excited state by the previous beta ray emission. In the case of Mn, the beta ray spectrum was shown definitely to consist of two groups; that of the other elements was simple. In all cases, gamma-gamma coincidences were found, showing the presence of more than one gamma ray per disintegration. An estimate of the number of gamma ray quanta per disintegration has been made.

**Estimates of yet unobserved half-lives of artificial radioactivities.** GEORGE DICKSON and E. J. KONOPINSKI, Indiana University.—Advantage was taken of three types of regularities supposed to exist among the binding energies of the stable isotopes to make predictions concerning the half-lives of possible artificial radioactivities which have not yet been observed. First, the "shell structure" periodicity was used. On the basis of the two other types of regularity, nuclei, differing in constitution by a neutron and a proton or by an alpha particle unit, are to be regarded as analogous. The latter, more stringent condition was mainly used, especially because of its apparent confirmation by the incidence of stable isotopes on an isotopic chart. The half-lives of series of known radioactivities, analogous according to the alpha particle criterion, were compared and, wherever regularity was observed, the lives of missing radio elements were estimated in agreement with the regularity. Finally, for the heaviest elements whose stability is most influenced by the coulomb repulsion, series of isotopes symmetrically placed with respect to the most stable isotopes were treated as analogous. This also resulted in some regularities from which predictions of half-lives were made.

**Effect of scattering in the source on measurements of beta spectra.** E. J. KONOPINSKI, Indiana University.—The approximate evaluation of the effect on the energy distribution of beta particles of scattering in

the source as a linear energy loss is sufficient to show that even the thinnest feasible sources may alter a "Fermi" distribution into a type better represented by a "K. U." curve. The criteria for the use of the empirically found linear range energy relation are fulfilled by portions of the spectra with energy greater than about 200 kv. for source thicknesses, corresponding to losses much smaller than the mean energy of the beta particles. The effect of large angle scatterings of the electrons is to spread the solid angle actually admitted by the measuring devices and thus effectively to thicken the source. The application of these considerations to test the consistency of a given experimental spectrum with a "Fermi" distribution can be carried out analytically. However, the straightforward correction of the experimental data to reveal the true distribution is handicapped by the inapplicability of the method to the lower part of the spectrum.

**X-ray diffraction in amorphous rubber.** C. M. PARSHALL and K. LARK-HOROVITZ, Purdue University.—Using monochromatic copper or molybdenum x-rays, diffraction patterns of purest latex and smoke sheet have been obtained from samples without any stress. The positions of nearest neighbors and the distribution of atoms along the chain have been determined by Fourier analysis. The number of nearest neighbors is found to be two, in agreement with the prediction from the rubber structure and in agreement with the observations of previous investigators. There are, however, differences between the structure of latex and smoke sheet, which will be discussed in detail in connection with the possible precision of the method.

**Test of the Schwarzschild equation for varying development temperatures.** LILLIAN THELMA COLEMAN and MASON E. HUFFORD, Indiana University.—The object of this research was to study the effect on the Schwarzschild exponent due to a range of temperature of development, keeping other factors constant as nearly as possible. All the photographic plates were developed, hardened, fixed, and dried under identical conditions; exposure time and temperature of development were the only factors varied. The investigation led to the conclusion that deviation of the Schwarzschild exponent p shows no systematic variation with development temperature. There is, therefore, no one temperature for which the average value of p will more accurately apply than for any other temperature. Therefore, p is not more constant throughout a wide range of exposures for one development temperature as compared with another. In general, then, it may be said that at no one temperature as compared to another does the Schwarzschild equation $E = It^p$ hold.

# Conductivity of Circular Openings in Helmholtz Resonators

R. B. Abbott and D. E. Allen, Purdue University

In analogy with the flow of electricity in conductors and liquids in pipes, the conductivity of the neck of a resonator is given as (disregarding end effects) $\frac{\pi R^2}{L}$ where R is the radius of the neck and L the measured length. Since the ends of the neck also have an effect on the conductivity, the effective length is greater than the measured length. This added length is a measure of the inertia of the air in the immediate neighborhood of the ends of the neck.

It has been noticed that the expressions for the conductivity of the neck of a Helmholtz resonator as given by different authors do not agree. They do agree in general that it is given by $\frac{\pi R^2}{L_1}$ where $L_1$ is here the effective length and is given by L plus a suitable end correction. It is in computng this end correction that the discrepancies occur.

Barton[1] gives the end correction as $\frac{\pi R}{4} = .785R$, Morse[2] gives $\frac{16R}{3\pi} = 1.171R$, Wood[3] uses 0.6 R, and Datta[4] and Olson and Massa[5] assume no end correction whatsoever. It is correct to make this last assumption if L and $L_1$ are very large and R is relatively small, but with standard Helmholtz resonators this is never the case.

Rayleigh[6] takes a circular opening in an infinitely thin wall and finds that the conductivity of this orifice is 2R. Since conductivity is the reciprocal of resistance, he adds this conductivity to that of a neck of finite length L as follows:

$$\begin{aligned} \text{resistance} &= \frac{1}{2R} + \frac{L}{\pi R^2} \\ \text{conductivity (K)} &= \frac{\pi R^2}{L + \frac{\pi R}{2}} \end{aligned} \tag{1}$$

It is evident that Barton's value of $\frac{\pi R}{4}$ assumes a correction at one end of the neck only. Morse has a correction at both ends, but he has used a value which is approximately correct only when L is very large. Wood's value of 0.6 R is that given by a correction at one end with no baffle present. Rayleigh's value of $\frac{\pi R}{2}$ assumes a correction at both ends of the neck and holds for small values of L.

In this study to determine the correct value for $L_1$, the apparatus consists of the following: (1) a set of ten spherical Helmholtz resonators, (2) a telephone receiver driven by a beat frequency oscillator, (3) a sound meter, and (4) a baffle board about three feet square.

[1]Barton, E. H., 1908. A textbook of sound. Macmillan.
[2]Morse, P. M., 1936. Vibration and sound. McGraw-Hill.
[3]Wood, A. B., 1930. A textbook of sound. Macmillan.
[4]Datta, A. C., 1917. A textbook of sound. Blackie and Son.
[5]Olson and Massa, 1934. Applied acoustics. Blakiston.
[6]Rayleigh, 1896. The theory of sound. Macmillan.

The resonator neck extends through a hole in the baffle so that its outside end is flush with the top surface of the baffle. The telephone receiver and microphone from the soundmeter, mounted on a swinging boom, are passed back and forth across the opening in the resonator. As the frequency of the receiver diaphragm approaches the resonance frequency of the resonator, an increased intensity will be shown by the soundmeter. When this is a maximum, the two frequencies coincide.

The following table gives the data and results of these experiments. Here the experimental K is found from the resonator formula,

$$N = \frac{C}{2\pi}\sqrt{\frac{K}{V}} \qquad (2)$$

where N = fundamental resonance frequency, C = velocity of sound in air, V = volume of resonator, and the theoretical value is from Equation (1).

TABLE I.—Comparison of Theoretical and Experimental Values for K

| Volume of Resonator cm.$^3$ | Fundamental Frequency N vib/sec. | Length of Neck L cm. | Radius of Neck R cm. | Experimental Conductivity K e.g.s. units | Theoretical Conductivity K e.g.s. units |
|---|---|---|---|---|---|
| 6220.0 | 129 | 0.25 | 1.93 | 3.58 | 3.57 |
| 1180.0 | 250 | 0.47 | 1.49 | 2.47 | 2.48 |
| 363.0 | 370 | 0.37 | 1.04 | 1.68 | 1.70 |
| 153.5 | 503 | 0.21 | 0.76 | 1.30 | 1.29 |
| 98.0 | 612 | 0.23 | 0.76 | 1.28 | 1.28 |
| 73.0 | 722 | 0.22 | 0.76 | 1.29 | 1.28 |
| 52.0 | 858 | 0.24 | 0.76 | 1.28 | 1.27 |
| 39.5 | 982 | 0.08 | 0.69 | 1.28 | 1.29 |
| 27.5 | 1080 | 0.20 | 0.64 | 1.08 | 1.07 |
| 21.0 | 1220 | 0.21 | 0.64 | 1.05 | 1.06 |

TABLE II.—End Corrections for Closed Pipes

| | N vib/sec. | $\lambda$ cm. | $R_1$ cm. | $R_2$ cm. | d cm |
|---|---|---|---|---|---|
| Pipe 1 | 420 | 62.0 | 59.2 | 18.2 | 2.30 |
| Radius = 2.85 cm | 480 | 71.4 | 51.3 | 15.6 | 2.25 |
| Theoretical end | 540 | 63.4 | 45.3 | 13.6 | 2.25 |
| Correction $d_1 = \frac{R}{4} = 2.24$ cm. | | | | | |
| Pipe 2 | 420 | 81.2 | 59.8 | 19.2 | 1.10 |
| Radius = 1.3 cm | 480 | 71.4 | 52.5 | 16.8 | 1.05 |
| $d_1 = 1.02$ cm | 540 | 63.6 | 46.7 | 14.9 | 1.00 |
| | 600 | 57.2 | 41.9 | 13.3 | 1.00 |

From this table it is evident that Rayleigh's value for the correction is right, but the question arises as to whether or not it is the same at both ends of the neck. It is necessary to make the obvious assumption that the outside end correction would be the same for a "closed" pipe as for a resonator. This outside correction for the pipe can be found since there is no inside correction; by taking the difference between this value and Rayleigh's value for the resonator, the inside end correction for the resonator can be obtained.

To determine this outside end correction, two pipes of different radii are used. One end of each is closed with a rubber stopper, which can be moved to vary the length of the pipe. The rest of the equipment and procedure are the same as described before.

Two resonance points $R_1$ and $R_2$ are found in each of the pipes for each frequency

$$R_1 = \frac{3\lambda}{4} - d \qquad (3$$

and

$$R_2 = \frac{\lambda}{4} - d \qquad (4)$$

where $\lambda$ is the wave length of the sound from the diaphragm and d is the experimental end correction.

Table II shows that the experimental and theoretical values for the end correction of the pipes check within experimental error. From this it can be assumed that the end correction of a resonator is evenly divided between the two ends of the neck when a baffle is used.

# The Characteristics of a Low Voltage Arc in a Magnetic Field

A. GUTHRIE and J. O. HANCOCK, Purdue University

For many disintegration experiments, as well as for other investigations, it is advantageous and often essential to have available an intense positive ion beam. During the last few years, the low voltage arc type of ion source has come into general use, for example, the arc sources of Tuve and Hafstad[1] and Zinn.[2] Livingston[3] recently adopted a modified Tuve and Hafstad arc source for use in the cyclotron. Following the work of Livingston, an arc of essentially the same type as that which is to be described was installed in the Purdue cyclotron. In order to investigate the properties of the arc, an experimental arrangement was constructed. The important feature of this arrangement is the use of a magnetic field to concentrate the discharge into a capillary.

The essential features of the experimental arc are shown in Fig. 1.

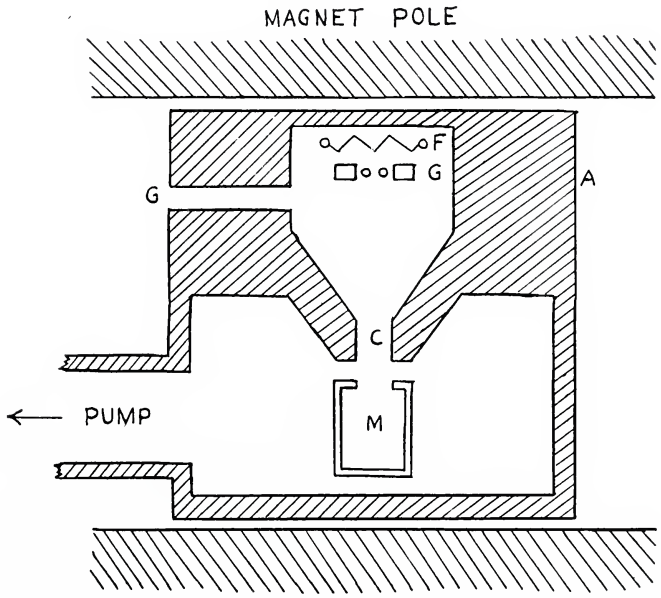


Fig. 1. Sectional drawing of the low voltage arc.

[1]Tuve, M. A., O. Dahl, and L. R. Hafstad, 1935. The production and focussing of intense positive beams. Phys. Rev. 48:241.

[2]Zinn, W. H., 1937. Low voltage positive ion source. Phys. Rev. 52:655.

[3]Livingston, M. S., M. G. Holloway, and C. P. Baker, 1939. Rev. Sci. Inst. 10:63-37.

A is a brass housing which serves as an anode for the discharge. The grid G, which consists of two 20 mil tungsten wires, parallel to each other and soldered across a rectangular hole cut in a copper disk, was inserted in order to determine whether it would have any effect on the characteristics of the discharge. The canal C is threaded so that capillaries, ranging in diameter from 20 mils to 200 mils, can be used. Hydrogen gas is admitted into the arc region through the inlet G, the flow of gas being controlled by a needle valve. Filament leads, grid, Faraday cage, and brass housing are all water-cooled. The magnet used gives field strengths up to 2500 gauss over an air gap of 3½ inches. The filament is heated by two 6-volt storage batteries connected in parallel. The arc voltage is obtained from a 220 volt D.C. line; the voltage for the Faraday cage is supplied by a rectifier unit. The pumping system consists of a Cenco megavac forepump and a modified Hickman oil diffusion pump, having a pumping speed of about 20 liters of air per second at a pressure of $10^{-4}$ mm. Hg. The discharge is struck between the filament F and the brass housing. The Faraday cage M is used to measure the strength of the ion current which issues from the capillary due to the action of the magnetic field.

Oxide coated and tungsten filaments have been used in this type of arc. The oxide coated filaments were made from platinum gauze having 70 wires per inch, the diameter of each wire being 0.003 inches, and were coated with a suspension of barium-strontium carbonates. The filament consisted of four layers of the gauze, a short length of 20 mil tungsten wire being spot-welded to each end perpendicular to its length to serve as a lead. The tungsten filaments were made of 20 mil wire in the form of a cone, with the apex of the cone directed towards the capillary.

The principal disadvantage of the oxide coated filament lies in the fact that the coating is removed in a relatively short period of time. The life of the coating was found to decrease with increased magnetic field strength, arc drop, and arc current. This can be explained by the fact that the positive ions in the arc region are accelerated towards the filament by the electric field and follow spiral paths due to the effect of the magnetic field. The destruction of the coating is believed to be due to bombardment of the filament by these positive ions. With an arc current of 1 ampere, a pressure in the arc region of about $3 \times 10^{-2}$ mm.Hg., and a magnetic field strength of 2000 gauss, the average life of a coating was about 20 hours. A tungsten filament can only be destroyed by actually raising its temperature beyond the melting point. Since the filament must be maintained at a temperature near its melting point for large electron emission, any slight change in filament current or arc current is likely to melt it. Also, at high values of magnetic field strength the force exerted by the magnetic field on the turns of the filament tends to short circuit them. In general, a tungsten filament will give longer service than an oxide coated platinum filament, but more precautions are necessary in its use.

In the case of an oxide coated filament, the volt-ampere characteristic of the discharge (see Fig. 2) indicates operation far from saturation and, therefore, the presence of a double sheath in front of the filament.

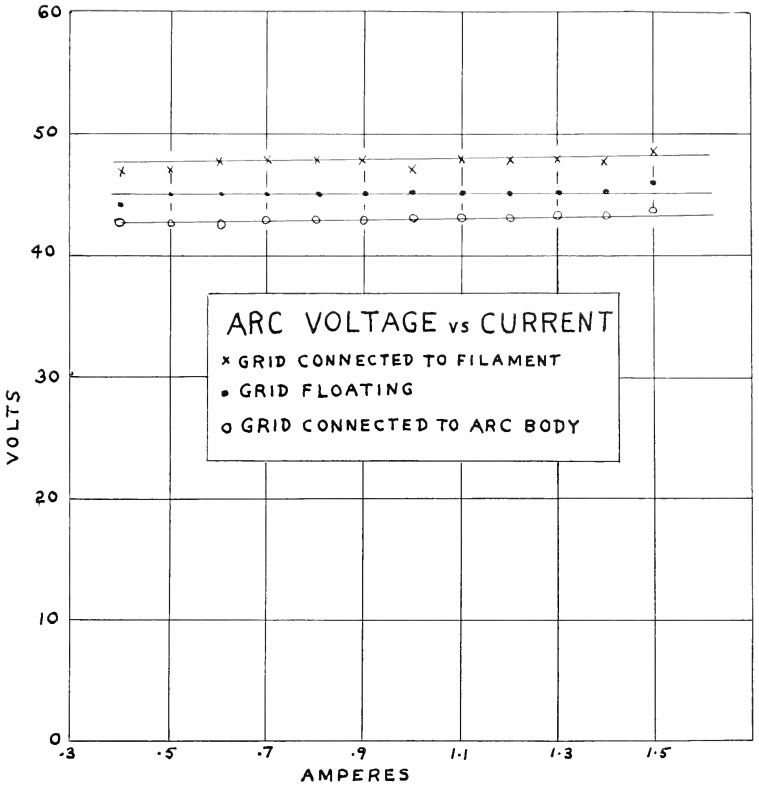


Fig. 2. Volt-ampere characteristics of the arc taken with an oxide coated filament at a pressure of 2.9 x $10^{-2}$ mm.Hg and a magnetic field strength of 1000 gauss.

It is to be observed that the manner in which the grid is connected has little effect on the characteristic. This can be expected if the grid behaves as a probe in the plasma of the arc. If a double sheath exists in front of the filament, it is to be expected that a change in magnetic field strength will not affect the characteristic of the discharge. The experimental results show that the arc drop is independent of the magnetic field strength.

The volt-ampere characteristic for the discharge with a tungsten filament is shown in Figure 3. The falling part of the curve shows that the filament is supplying a sufficient number of electrons to maintain a double sheath. The rising portion of the curve suggests that the filament is now unable to satisfy the demand for electrons and, therefore, the arc voltage must increase. This portion of the characteristic corresponds to operation of the filament at saturation. Since a double sheath does not exist in this case, a change in magnetic field strength should affect the characteristic. It was found that an increase in magnetic field resulted in a decrease in the arc drop, which follows directly from the idea of positive ion bombardment.

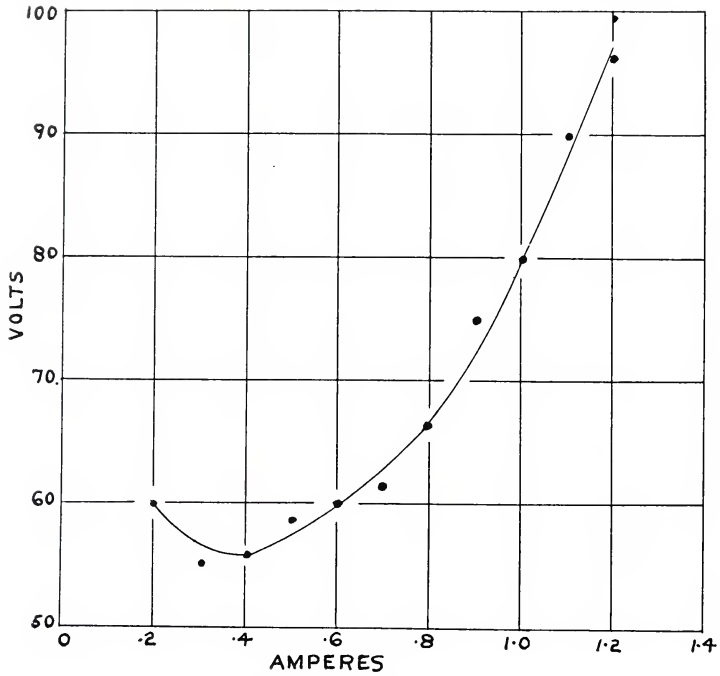


Fig. 3. Volt-ampere characteristic of the arc with tungsten filament at a pressure of 3 x $10^{-2}$ mm.Hg and a magnetic field strength of 1000 gauss.

It is believed that the ions collected by the Faraday cage are formed in the capillary itself since the potential gradient in the arc region will prevent ions from leaving that region and entering the capillary. The number of ions formed in the capillary should depend on the number of electrons entering it, and this in turn will depend on the cross-section of the capillary, on the value of the magnetic field strength, and on the value of the arc current. It was found that the ion current collected by the Faraday cage definitely increased with the size of capillary and strength of magnetic field. In making these measurements, a negative potential with respect to the filament was applied to the cage in order to prevent electrons from reaching it. Fig. 4 shows the relationship between cage current and arc current for the case of an oxide coated filament. Similar curves were obtained when tungsten filaments were used. The curves for the oxide coated filament show that the Faraday cage current increases almost linearly with the arc current. The manner in which the grid is connected has little effect on the curves obtained.

In order to obtain some idea of the number of secondary electrons being produced by positive ion bombardment of the Faraday cage, curves of cage voltage against cage current were plotted. Some typical curves are shown in Fig. 5. The shape of the curve was found to be practically independent of all variables except the arc drop. The steeply rising part

of each curve corresponds to the case where electrons are able to reach the cage. The curve flattens out at about 100 volts on the cage, indicating that electrons having energies up to this value are reaching the cage. This voltage corresponds very closely to the arc drop. The portion of the curve for voltages above this value has a slight slope which is believed to be due to the production of secondary electrons by positive ion bombardment of the cage. The proportion of secondary electrons in the Faraday cage current was obtained by measurement of the slope of the curve, and the results agree fairly well with those of Healea and Chaffee.[4]

In order to obtain large ion currents then, one requires a large magnetic field strength, a large capillary, and a large arc current. The

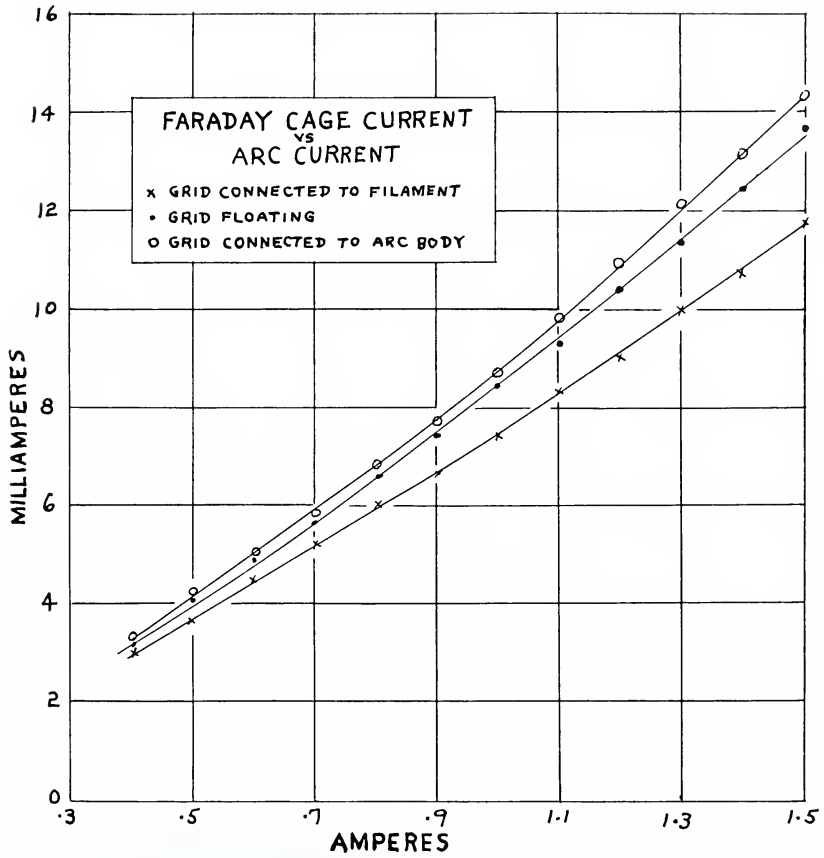


Fig. 4. Dependence of Faraday cage current on arc current for the case of an oxide coated filament. Pressure in the arc region = 2.6 x $10^{-2}$ mm.Hg. Magnetic field strength = 1000 gauss. Arc current = 1.5 amperes.

[4]Healea, M., and E. L. Chaffee, 1936. Secondary electron emission from a hot nickel target due to bombardment by hydrogen ions. Phys. Rev. 49:925-930.

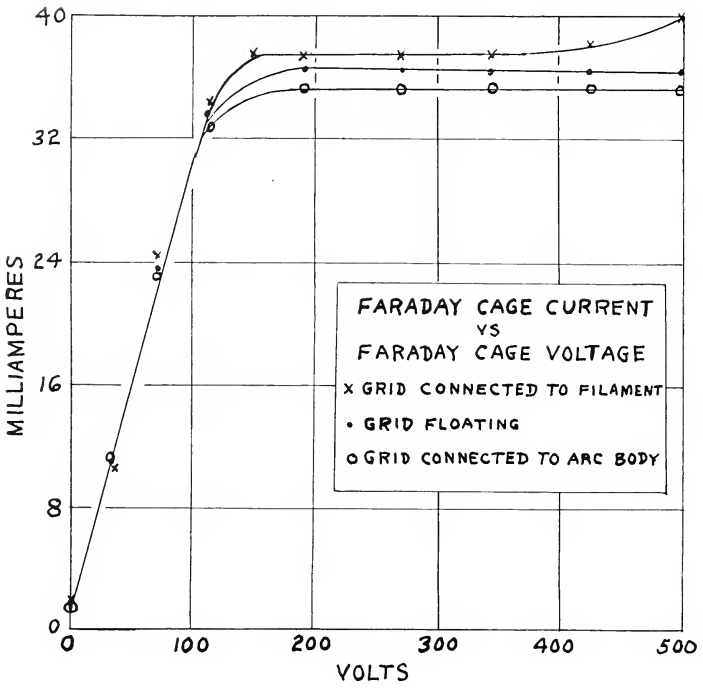


Fig. 5. Dependence of Faraday cage current on Faraday cage voltage for the case of an oxide coated filament. Pressure in the arc region = 2.9 x $10^{-2}$ mm.Hg. Magnetic field strength = 1000 gauss.

values of these quantities must be chosen to give a reasonable filament life and at the same time satisfy the pressure requirements outside the arc region and give a reasonable rate of gas consumption. With an oxide coated filament, it is quite feasible to use an arc current of 1 ampere, a pressure in the arc region of $3 \times 10^{-2}$ mm.Hg., a magnetic field strength of 2000 gauss, and a capillary of 200 mils diameter in order to obtain a Faraday cage current of about 25 milliamperes with a reasonable filament life. With a tungsten filament, currents as high as 50 milliamperes have been obtained.

In the near future, this arc will be used as an ion source for the D-D reaction. Following this, an attempt will be made to take the beam out of the magnetic field and analyze it by means of a magnetic spectrograph.

**Acknowledgment**

It is indeed a pleasure to record our indebtedness to Professor W. J. Henderson, who suggested the problem and gave much valuable assistance.

# The Alpha Particle Bombardment of Magnesium

R. L. Doran and W. J. Henderson, Purdue University

The artificial radioactivity of magnesium produced by alpha particles was reported in 1934 by the Joliets (1) in their first paper on artificial radioactivity. It was subsequently shown that the main effect is the production of $Al^{28}$ with a half life of 2.35 min. This has been verified from the work with deuterons and neutrons. Magnesium has three stable isotopes and beyond the formation of $Al^{28}$ by

$$Mg_{12}^{25} + He_2^4 \longrightarrow Al_{13}^{28} + H_1^1$$

there is the possibility of forming unstable $Si^{27}$ and $Al^{29}$ as follows:

$$Mg_{12}^{24} + He_2^4 \longrightarrow Si_{14}^{27} + N_0^1$$

$$Mg_{12}^{26} + He_4^2 \longrightarrow Al_{13}^{29} + H_1^1$$

It has been reported that three periods do result from this bombardment (2). They are given as 2.3 min., 7 min., and a period measured as being greater than 11 min. The measurements were made, using alpha particles from naturally radioactive bodies, and, as a consequence, the energy was very much below that available at present. We have used the identical piece of magnesium from which these measurements were made and have bombarded it with the 16 MV alpha particles from the Purdue cyclotron. This stream of particles is equivalent in numbers to

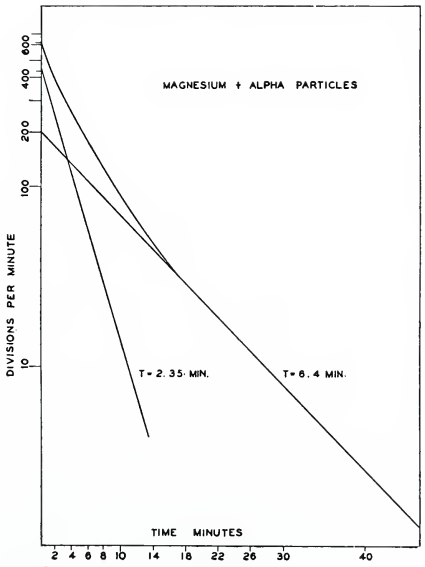


Fig. 1.

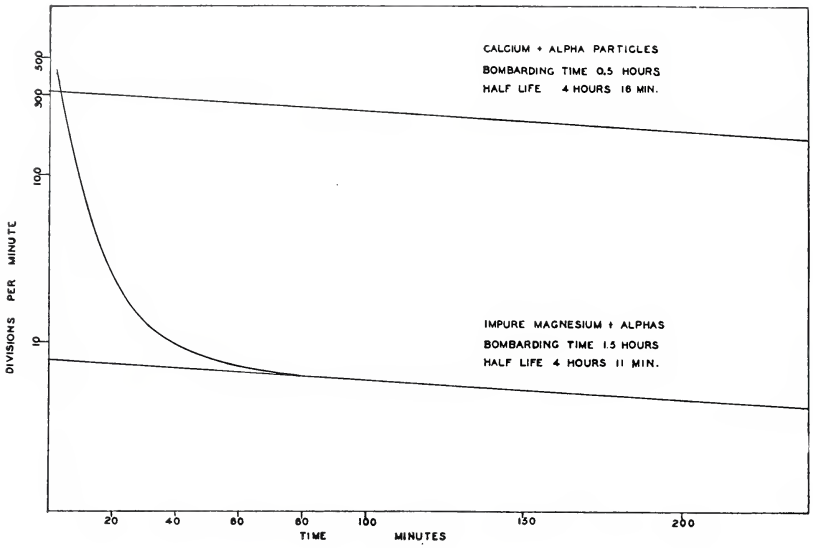


Fig. 2.

that from two or three grams of radium but of very much greater energy. The periods of decay are found to be 2.35 min., 6.4 min., and 4 hr. 11 min.

However, measurements taken from a very pure piece of magnesium supplied by Dow Chemical Company show that under alpha particle bombardment only the periods 2.35 and 6.4 min. are present. Figure 1 shows the decay curve from the pure sample of Mg. The fact that the 4-hour period could not be found suggests that it was due to an impurity in the original sample. Of the likely impurities in Mg, calcium produces

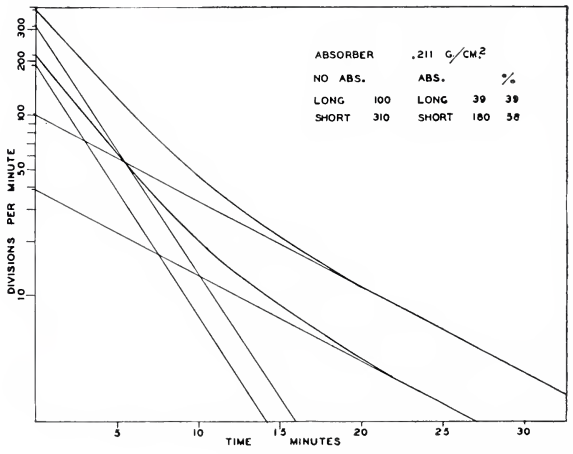


Fig. 3.

this period under the bombardment of alpha particles. Radioactive scandium[43] is produced in this reaction (3) and decays with a period of 4 hr. 16 min. With a pure calcium target, the 4-hour activity is found to be 300 times greater than in the impure Mg target. An impurity of ⅓ of 1% of calcium in the magnesium would explain the presence of the 4-hour activity in the original sample. In figure 2 a comparison of the 4-hour activities in pure calcium and the impure Mg is shown.

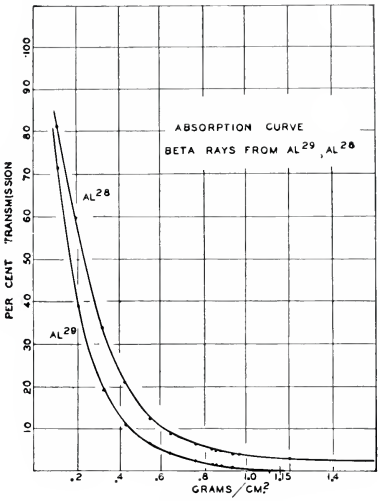


Fig. 4.

Cloud chamber tracks and magnetic analysis show that the emitted particles are beta particles. The decay of $Al^{28}$ with the emission of beta particles has been definitely shown to have a half-life of 2.35 min. (4). The fact that we do have beta particle emission corresponding to the 6.4-minute decay means that this period is due to the $Al^{29}$ decay. Just recently it has been shown by proton bombardment of Al that $Si^{27}$ has a half-life of 3.7 sec. (5). In the present experiment, such a short lifetime would not be observed, but there are theoretical reasons to believe that the formation of $Si^{27}$ will not take place at the present energy of alpha particles.

Absorption measurements were made to determine the upper limit of the beta ray energies, using an electroscope and aluminum absorbers. In plotting this absorption curve, a special technique must be used because we are working with two radioactive bodies whose half-life periods are comparable. Otherwise, one could read the absorption data directly. It was necessary that each point on the absorption curve be made with a new target. For each, target readings were taken alternately with and without the absorber. One curve shows the activity with the absorber in place, and one shows the activity without the absorber. This would eliminate the error due to different bombardment conditions for different sources. The 6.4 min. and 2.35 min. decay lines could be drawn

on the curve and extrapolated to zero recording time, that is, the end of bombardment. Thus, for one particular thickness of absorber, we would know what activity was due to each period with no absorber and also the activity for the absorber in place. The absorption for that point would then be the ratio of the two activities for the 6.4 min. period and a similar ratio for the 2.35 min. period. A sample point is calculated for .211 gm/cm$^2$ of absorber in figure 3.

The resulting absorption curves in figure 4 show in the case of $Al^{28}$ the absorption of the beta rays on a gamma ray background. For $Al^{29}$ the beta absorption is all that is evident. Apparently, no gamma rays are connected with this reaction, or, if any at all, they are too weak to be detected by this method. The maximum range of the beta particles from $Al^{29}$ is approximately 1.15 gm/cm$^2$. This, according to Feather's Rule (6) corresponds to an energy of 2.4 MV. This value is checked within the limits of experimental error by the mass absorption coefficient of beta rays in Al. This value of 5.35 corresponds to an upper limit of 2.3 MV. From cloud chamber photographs (7) the beta ray spectrum is shown to be continuous and of a maximum value of 2.5 MV. We conclude, therefore, that the maximum energy of the beta rays from $Al^{29}$ is $2.4 \pm .2$ MV.

## References

1. Curie, I., and F. Joliot, 1934. Comptes Rendus **198**:254-256. Journ. de Physique et le Radium **5**:153-156.

2. Ellis, C. D., and W. J. Henderson, 1936. Proc. Roy. Soc. **156**:358.

3. Pool, Cork, and Thornton, 1937. Phys. Rev. **52**:41.

4. Amaldi, D'Agostino, Fermi, Pontecorvo, Rasetti, Segre, 1935. Proc. Roy. Soc. **149**:522.

5. Kuerti, G., and Van Voorhis, 1939. Phys. Rev. **56**:614.

6. Feather and Dunworth. 1938. Proc. Roy. Soc. **168**:566.

7. Henderson, W. J., and H. A. Bethe. (In print). Phys. Rev.

# A Simple Method for Obtaining the Solutions of Dirac's Equation for a Free Particle in Spherical Coordinates

J. F. Carlson, Purdue University

The Dirac wave equation for a free electron.

$$(E - c(\vec{\alpha} \cdot \vec{P} - \beta mc^2)\Psi = 0 \tag{1}$$

may for convenience be written in the form

$$(\epsilon + i\vec{\alpha} \cdot \nabla - \beta)\Psi = 0 \tag{2}$$

where the units are chosen so that $\frac{h}{2\pi} = \frac{1}{2\pi}$ times Planck's constant; m, the mass of the electron, and c, the velocity of light, are put equal to unity. In these units the unit of length is $\frac{h}{2\pi mc}$, the unit of time is $h/mc^2$, and the unit of mass is the electron mass. $\epsilon$ is the total energy in these units, $-i\nabla$ the operator representing the momentum, and $\vec{\alpha}$ and $\beta$ the four row and column Dirac spin matrices.

Let us call the operator $\epsilon + i\vec{\alpha} \cdot \nabla - \beta = H$ and define the operator $K = \epsilon - i\vec{\alpha} \cdot \nabla + \beta$. Consider the product HK. By using the well-known properties of the $\alpha$'s and $\beta$, namely,

$$\begin{aligned} &\alpha_x\alpha_y + \alpha_y\alpha_x = 0, \text{ etc.} \\ &\alpha_x\beta + \beta_x = 0, \text{ etc.} \\ &\alpha_x = \alpha_y^2 = \alpha_{2z} = \beta^2 = 1 \end{aligned} \tag{3}$$

we find for the product of H and K that

$$HK = \nabla^2 + \epsilon^2 - 1 \tag{4}$$

where $\nabla^2$ is the Laplacian. Defining $\epsilon^2 - 1 = k^2$, we have $HK = \nabla^2 + k^2$. Now consider the partial differential equation

$$(\nabla^2 + k^2)\Phi = 0 \tag{5}$$

and let us express $\nabla^2$ in spherical polar coordinates. The solutions $\Phi$ of this equation are well-known.

$$\Phi = \frac{R(r)}{r^{1/2}} S(\vartheta, \phi) \tag{6}$$

where R(r) is a Bessel function and $S(\vartheta, \phi)$ is a spherical harmonic. Now let us return to our original equation, $H\Psi = 0$ (2).

If we put $\Psi = K\Phi$ we obtain the differential equations $HK\Phi = 0$ (7)

so that $\Psi = K\Phi$ is a solution of the Dirac equation for a free particle in spherical polar coordinates. Since the operator K is a matrix, each column of the matrix gives us the four components of the solution.

The four columns, then, are the four independent solutions corresponding to the two independent orientations of the spin and to the two possible values of the energy associated with a given value of the momentum.

# PSYCHOLOGY

Chairman: AMMON SWOPE, Purdue University

The section on psychology was well attended, and most of the papers read were followed by general discussion. Some of the papers had marked vocational or industrial implications.

R. A. Acher, of Indiana State Teachers College, was elected chairman of the section for 1940.

## ABSTRACTS

**The civil aeronautics authority flight training program—psychological problems.** AMMON SWOPE, Purdue University.—Preliminary to the investigation, letters were sent to 30 schools engaged in training pilots for aviation service. Reports of these institutions showed that no consistent scheme of selecting pilots was followed. Some of the common forms of selection placed emphasis on mathematics, physics, English, or high school graduation. In many cases high school graduation is not required. After a critical study of various articles, it was found that psychological problems could be organized under such headings as acceleration, altitude, aptitude, occupations, orientation, sickness, and vision. It is impossible to give any single conclusion to the series as here presented, but many of the findings in our laboratories might be adapted to the selection of pilots.

**An experimental study of changing patterns of response during conditioning of dogs.** IRVIN S. WOLF, Indiana University.—Six mongrel dogs were trained by the buzz-shock technique with shock delivered only to the right rear limb. Simultaneous recordings were made of the movements of all four limbs and of breathing throughout a training series involving 400 stimulations. Conditioned behavior was found to be diffuse and qualitatively different responses were observed for the various animals and for the same animal at different stages of training. Abrupt changes in systematic behavior resembling Krechevsky's "hypothesis behavior" were indicated. Curves describing both the acquisition of the right rear limb flexion and the elimination of less adaptive behavior in other members suggest both the usual increasing conditioning curve and the decreasing trial-and-error curve for conditioned behavior recorded simultaneously. Two general methods of development of the adaptive response were found. Some animals gradually built up the coordination between the right foot response and the conditioned stimulus. Others developed conditioned struggle and later eliminated the responses in the non-shocked members.

**A study of teachers' and pupils' attitudes.** HARRY MASON, Purdue University.—Social attitudes of over 900 pupils in social studies courses in Arsenal Technical High School in Indianapolis, as well as those of

their teachers, were measured at the beginning and end of a semester's work. Relationships found between attitudes and factors concerning the school and out-of-school environments of pupils were studied for their possible significance to the teaching of the social subjects as well as for their theoretical interest.

**Some recent applications of psychology in industry.** JOSEPH TIFFIN, Purdue University.—This paper is a summary of recent research in industrial psychology concerning selection tests, job analysis by psychological tests, and possibilities for training. The validation of selection tests for assembly work and inspection work in specific plants is evaluated with a description of the tests finally adopted by a number of representative industries for use in actual employment. Possibilities of job analysis by test is illustrated by means of specific experimental results from the steel industries. These results show how employees may be measured by means of testing situations which determine their efficiency on various aspects of the job. The use of the above results in a training program designed to develop efficiency in new employees in the most economical manner is presented.

**The effect of physical performance on the eyes.** LYLE TUSSING, Purdue University.—The study shows the effect of fatigue on various eye functions. Male subjects were used. Fatigue had been administered in several different ways. Changes in fatigue are subjectively recorded on a seven-point scale. The eye tests were given before and after submitting the subject to the fatigue situation. The eyes are affected by fatigue even though the fatigue is of such nature as not to call for eye strain of itself.

**A preliminary study of information in the field of home economics education held by students in entering the home economics departments of colleges in Indiana.** ALMA LONG, Purdue University.—This is part of an extended program planned for the study of curriculum materials and some results of teaching in the field of home economics education at the high school level. The results of a test which was given to students entering the home economics departments of colleges in Indiana have been analyzed to test the usefulness of such an instrument in determining the kind and extent of specific information acquired previous to college entrance, to suggest the relationship such bodies of knowledge may have to the curriculum in home economics offered at the high school and first year college levels, and to suggest areas in which further research might be needed. Questions were raised also concerning college training which takes into account differences in the proficiency of students and the high school and college teaching which produces maximal individual development.

**The relationship between marital compatibility and personality traits of husbands and wives as rated by self and spouse.** E. LOWELL KELLY, Purdue University.—Seventy-six husbands and their wives were each asked to compare themselves on 36 personality traits. For example, a husband was asked to rate both himself and his wife on such traits as honesty, cooperativeness, sincerity, punctuality, and initiative; she was

asked to rate both herself and her husband on the same traits. All returns were anonymous. Each husband and wife also filled out a set of questions which were scored to yield a measure of the degree of marital happiness achieved by the couple. In general, happily married husbands and wives tend to rate their own personalities above average but rate their spouses even higher. Conversely, couples with low compatibility scores tend to think less well of themselves and rate themselves as superior to their spouses.

**The readmitted student.** M. L. FISHER, Purdue University.—Every year a considerable number of students are dropped from University rolls by reason of poor scholastic performance. Studies were made of the students dropped during scholastic years and summer sessions of 1931-32, 32-33, 33-34, 34-35, 35-36, involving a few over 1,100 students. Data were tabulated and analyzed. In round numbers 22% of those dropped and readmitted were later graduated and 7.5% were still in school in Purdue University. No information is given concerning those who may have gone to other institutions and graduated.

# ZOOLOGY

Chairman: C. P. HICKMAN, DePauw University

About 75 persons were present during all or a part of the session of the section on zoology. Sixteen papers were presented. An outstanding one of these, as indicated by interest and discussion, was that by W. A. Hiestand, Helen J. Ramsey, and Doris M. Hale on the physiological effects of cigarette smoking.

W. A. Hiestand, Purdue University, was elected chairman of the section for 1940.

## ABSTRACTS

**The effects of cigarette smoking on metabolic rate, heart rate, oxygen pulse, and breathing rate.** W. A. HIESTAND, HELEN J. RAMSEY, and DORIS M. HALE, Purdue University.—To determine the effects of smoking on various functions, 39 subjects of both sexes, some confirmed smokers and some light smokers, were used in a non-basal metabolic state. A half-hour rest period was allowed before the test, but no precautions were taken to secure post-absorptive repose. A second series was undertaken with 20 habitual smokers in a basal condition of post-absorptive repose. Determinations were made for each individual at 15-minute periods following smoking to determine the durability of the effects. The non-basal subjects showed considerable individual variability, marked increases and decreases being noted in each function. The average increase in metabolic rate was 7.7% in men and 9.9% in women; the average increase in heart rate was 5.9% in men and 6.4% in women. In the basal subjects the metabolic rate rose 14.3% immediately after smoking, then fell slightly and rose again; the duration of the effect beyond 45 minutes after smoking was not determined. The heart rate rose 16.7% immediately after smoking, quickly fell to slightly above normal, and was 2.6% below normal at the end of the experiment. The oxygen pulse first dropped to 2.1% below normal and then continued to rise, reaching 11% at the end of the experiment. The breathing rate first fell to 7.4% below normal and then rose to 1.1% below normal at the end of the period. The behavior of the oxygen pulse indicates an immediate decrease in the adaptability of the heart with a gradual recovery.

**The life cycle of *Monorcheides cumingiae* (Martin) (Monorchidae, Trematoda).** W. E. MARTIN, DePauw University.—The life cycle of *Monorcheides cumingiae* involves the development of the larval stages in the marine clam, *Cumingia tellinoides*, and the maturation experimentally in the flounder and eel. The anatomy, effect on the clam, and the ecological relationships of the parasite are considered.

**A note on the occurrence of a syrphid larva as an accidental parasite of man.** HELEN L. WARD, Purdue University.—A parasite from the intestine of a woman from Oaktown, Indiana, has been identified as the larva of a syrphid fly, possibly *Eristalis tenax* (Linn). The single speci-

men was sent to Dr. H. E. Enders by Prof. Beghtel of Evansville College and referred to the writer for study. The larvae of syrphid flies have been reported from time to time as human parasites. Their presence in the intestine is due to accidental ingestion of the eggs or larvae in water or food. The symptoms which have been described are nervousness, indigestion, headache, and emaciation.

**Panting and temperature regulation in the chicken.** W. C. RANDALL and W. A. HIESTAND, Purdue University.—Panting in the chicken as a response to rising body temperature was demonstrated in this investigation. That panting is regulated by a center separate from the respiratory center is indicated by the use of centrally acting drugs. Reflex inhibition of panting following external chilling invariably occurred even though no appreciable drop in internal temperature was noted. Above a certain upper critical temperature level the panting mechanism begins to fail, resulting in a reduced rate. Central depression reduces panting rate, and deep anesthesia abolishes it entirely, light anesthesia raising the panting temperature. Depressant drugs affect the panting center independently of the respiratory center. Central stimulation (lobeline) results in increased panting and respiratory movements followed by a longer period of increased sensitization of the panting mechanism. This sensitization is apparent in a lowered panting threshold, an increase in panting rate in relation to internal temperature, and a greater maximal panting rate.

**Egg production in trematodes with special reference to *Spelotrema nicolli* (Microphallidae).** R. M. CABLE, Purdue University.—In studying the life history of *Spelotrema nicolli*, egg formation has been observed repeatedly. The oocyte, separating gradually from the ovarian mass while the preceding egg is formed, is propelled down the oviduct and passes into the ovijector which contracts instantly, forcibly expelling the oocyte into the ootype. This produces an enlargement of the beginning of the ootype where currents produced by long cilia rotate the oocyte rapidly for a few moments, facilitating fertilization. The zygote, forced along the ootype by a series of contractions until it reaches the opening of the vitelline reservoir, pauses there and is provided with a mass of vitelline material which is squeezed into the ootype by a series of contractions of the vitelline reservoir. Excess vitelline material and occasional sperms are voided through Laurer's Canal. The zygote surrounded by this material then passes just beyond the openings of the shell gland into the egg chamber, the muscular walls of which mold the egg as the shell material hardens. The egg is kept in constant motion by contractions of the egg chamber and may be turned end for end several times before the shell is completed. A much stronger contraction now begins back of the finished egg and ejects it into the uterus; at the same moment another oocyte moves down the oviduct, and the process is repeated. In one instance, it was noted that 24 minutes elapsed between the descent of one oocyte and that of the succeeding one. At the relatively high body temperature of the host, however, egg formation must proceed much more rapidly than

observed at room temperature, as indicated by the number of eggs present in young worms.

**Notes on *Miranda aurantia*.** FRANCIS WENNINGER, University of Notre Dame.—*Miranda aurantia* is the name that should be used although at least 28 writers mention neither the genus nor the species. The peculiar position of the eyes, some prominences, and other internal features, mating and egg-laying, and the disposition of the nest are noted.

**Preliminary limnological survey of Dewart Lake, Kosciusko County, Indiana.** MURVEL R. GARNER, MARKLAND MORRIS, and GLEN WOOD, Earlham College.—A preliminary limnological survey of Dewart Lake was made during the summer of 1939 with a view to making a continuous comparative study through a period of years. The usual limnological data with respect to physical, chemical, and biotic determinations were taken. The lake, which lies between Tippecanoe and Wawasee, is a relatively small one and has large areas of shallow water. The significance of the ratio of shallow water and deep water is being studied from the standpoint of biotic productivity in order to make comparisons with some of the nearby larger lakes. The significance of an artificial raising of the level of the lake many years ago by a low dam is also under study. Preliminary reports on data obtained are tabulated.

**Insects of Indiana for 1939.** J. J. DAVIS, Purdue University.—This paper is a discussion of the major insect problems in Indiana during the past year, with explanation of causes of insect abundance or scarcity, and new developments in insect control.

**Records of Indiana dragonflies, X. 1937-1939.** B. ELWOOD MONTGOMERY, Purdue University.—New county, seasonal, and other records of Odonata, based upon collections of 266 specimens (29 species), 414 specimens (49 species), and 1455 specimens (54 species) made in Indiana in 1937, 1938, and 1939, respectively, are listed. Observations showing the establishment of *Celithemis fasciata* Kirby, a southern species, at a lake near Oakland City, are noted. Ecological notes and discussions of variations observed in certain species are given.

# Recent Experimental Work on the Mammalian Adrenal Cortex

C. P. Hickman, DePauw University, and R. R. Overman,
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For some time the authors of this paper have been investigating the effects on the mitochondria and other structures of the adrenal cortex in white mice when Collip's adrenotropic hormone is injected into them under control conditions. In connection with certain aspects of this work, and as a background for it, we are presenting this review of some of the recent experimental modifications of the mammalian adrenal cortex. In this account we wish to emphasize the general histological structure of the cortex and the prevailing views regarding its formation. Without a doubt much of the knowledge about the adrenal gland has been derived from the study of its physiological cytology. The very fact that the adrenals have had so many functions assigned to them in recent years implies great complexity in their physiological action. Although there seems to be a certain amount of uniformity in their structure among various mammals, it is not possible in our present state of knowledge to homologize all their details. There is considerable diversity in the histological components of the adrenal cortex, and it may be that such diversity of structures is associated somewhat with functional differences.

As a general thing, the functions of the adrenal cortex are even more shrouded in mystery than are some of the other endocrine glands. A list of symptoms displayed by adrenalectomized animals will give some idea of the ramifications of the action of the cortex. In recent years, it has been shown that animals without adrenals and without any type of replacement therapy show sodium excretion above normal, marked dehydration, rise in blood urea, retention of potassium in the blood, loss of glycogen storage, decrease in blood glucose, hypotension, pigmentation of the skin, susceptibility to toxins, gonadal disorders, lactation disturbances, and several other effects. In view of such varied functions, it seems easier and more to the point to enumerate the things this much-functioning gland does not do.

**General histological structure of the mammalian adrenal cortex.—** It is well known, of course, that the adrenal glands in mammals consist both structurally and functionally of two distinct separate parts, the cortex and the medulla. Each of these parts, it is also well known, has its own separate and distinct origin. The comparative anatomy of the two regions, as traced through the different vertebrate groups, is a very interesting one.

As a general feature, the adrenal cortex is formed of cords of cells, between which lie reticular tissue and capillaries. These cords are generally two cells wide. Since the shape and arrangement of these cords differ throughout their course, the cortex has been divided in a somewhat arbitrary manner into three zones: an outer or *zona glomeru-*

*losa*, a middle or *zona fasciculata*, and an inner or *zona reticularis*. As we shall point out later, we should not adhere to this zone division rigidly. It simply represents a convenient way of understanding the main features of the cortex.

There is considerable variation in cell types in the cortex among the different layers. In the *zona glomerulosa*, which is the narrowest of the three, the cells are columnar or sometimes pyramidal, arranged in ovoid groups or in small arcs which cap the next layer, the *zona fasciculata*. The nuclei of these cells stain deeply. Lipoid droplets are few in number.

The *zona fasciculata*, which makes up the widest part of the gland, as a usual thing, consists of larger cells chiefly polyhedral in shape. In the outer fasciculata region the cells stain rather lightly, and there are numerous lipoid droplets which, when dissolved away, give this region a spongy appearance. There are often two or more nuclei in each cell. In the inner part of the fasciculata the cells diminish in size and contain basophilic granules which stain deeply with iron hematoxylin. The cells of this region are arranged in cords.

The innermost zone, the *zona reticularis*, has its cells arranged in anastomosing cords. The outer cells of this region are similar to those in the fasciculata zone, except that they have fewer lipoid droplets. In other parts of the zone there are two distinct kinds of cells, light and dark. The light cells are more numerous than the dark ones and have rounded contours. The dark cells are smaller with a deeply staining cytoplasm and small shrunken (pyknotic) and hyperchromatic nuclei. Light cells have fewer mitochondria and lipoid droplets than the dark cells. The difference between the two kinds of cells seems to be a matter of difference in lipoid emulsification. Light cells have their protein material scattered among small lipoid droplets; dark cells have larger lipoid droplets, and the protein part, which stains darkly, here shows up to a better advantage. There are many transitional forms between the light and dark cells. There is also much cellular debris in the reticularis zone. The light and dark cells probably represent stages of degenerating, senescent cells.

According to most authorities who have studied the problem, there is a growth from without inward in the cortex, and there is a corresponding continuity of cell types. It is the belief of most that there is a normal progression of the cell from the spindle, fibroblast-like cell of the capsule through the ovoid or prismoid shapes of *zona glomerulosa* and *zona fasciculata* to the small heterogenous, hyperchromatic cells of the reticularis zone. In the reticular region the presence of cellular debris would tend to show a breakdown of old cells whose function and shape have changed through the zonal progression from capsule to medulla. Most workers agree with Hoerr ('31) that the different functions of the cell types are independently derived or else are the different functional states of the same cell.

Most cases of mitosis are found in the fasciculata zone or in the border between the glomerulosa and the fasciculata. Usually only a few are found in the reticularis layer, and these are chiefly in young animals.

**The adrenal X zone.**—In some mammals, especially in mice, and possibly to some extent in the cat, rat, human, and a few other species, a so-called X zone has been described by many writers. This zone has often been included in the *zona reticularis* by most observers, but others regard it as a separate zone, although a transient one. It is not present in the adrenal of the adult male mouse although it first appears in both sexes at about three weeks of age. The cells of this zone are characterized by being small and free from lipoid droplets and staining darkly. In mice which are early castrated (before five days of age) the zone may develop to the extent of one-third or more of the entire cortex. In the female the X zone is normally larger and persists for a longer time, disappearing in that sex in the middle of the first pregnancy or later in the non-pregnant female. In the female its growth and development are unaffected by ovariectomy.

In mice castrated after sexual maturity, when the primary X zone has disappeared, a secondary X zone appears but disappears about 100 days later. It is thus seen that the spontaneous manifestation of the X zone is restricted to a limited portion of the life cycle. It has also been shown that castration changes in the mouse can be inhibited by injections of male hormones. Howard ('39) recently found that there is a correlation between the development of the seminal vesicles and that of the X zone. These and other experiments have given rise to the belief that gonadal hormones are produced in regions outside of the reproductive system, but in the course of development this function becomes concentrated in the gonad. However, in dwarf mice X zones fail to develop after castration. This may mean that the pituitary may also be involved in some way.

In rats, Howard ('38) has shown the presence of a zone, similar in most ways to the X zone of mice, which she calls the juvenile cortex. This zone appears well developed in rats of both sexes at three weeks of age and has almost disappeared in 40 days. This juvenile cortex shows no age differences and is little influenced by castration. The juvenile cortex is, for the most part, transformed into the adult reticular zone although some of its cells tend to persist in an isolated condition.

Man shares with mice in having the most X zone development, but in this case the zone degenerates soon after birth.

In the rabbit there are actually four zones in the adrenal cortex. The innermost interlocks with the medulla, but it is not known whether this inner zone may or may not be homologous with the X zone of the mouse.

**Cytoplasmic inclusions of the different zones of the adrenal cortex.**—Many investigators have described the mitochondria of the mammalian adrenal cortex, and, as a general thing, there is agreement among them regarding the shape and arrangement of these cytoplasmic inclusions. In the *zona glomerulosa*, where they are unusually abundant, the mitochondria are found chiefly in the form of threads and short rods; in rarer cases, they are in the form of granules. In some cases, these threads have beaded or clubbed ends. In the *zona fasciculata* they are found in the form of granules and are placed in the spaces between the

lipoid inclusions. In the *zona reticularis* most of the mitochondria are in the form of rodlets which often clump together in a characteristic fashion. Although some writers have reported that the mitochondria are less abundant in this zone than in the others, this view has probably arisen from poor fixation. Nearly all workers agree that the *zona reticularis* is the most difficult part of the cortex to fix. Whenever good fixation is employed, the reticularis will show as many of the inclusions as the other zones. However, it should be pointed out that there is considerable variation in the distribution of mitochondria in the cortex of various mammals. In some cases, there is a marked tendency for them to be accumulated in clusters near the nucleus; in others they are scattered throughout the cytoplasm. Such differences cannot always be made accountable on the basis of differences in technique. The fact that mitochondria are more abundant in cells where there is little lipoid proves nothing, for they may here show up to greater advantage.

In the adrenal cortex the Golgi apparatus appears chiefly in the form of a network of filaments with varicosities. Around this network there are often small spheres. There is also a fairly close relationship between the Golgi apparatus and the cell vacuoles.

**Lipoid inclusions of the different zones.**—Lipoid inclusions of some form are found in all the cortex zones. They are especially abundant in the fasciculata cells, and, when the lipoid is dissolved out, the cells present a peculiar vacuolated cytoplasm. From this appearance the cells here are called spongiocytes. The *zona reticularis* contains much less lipoid, and the light cells found in some contain little or none. Zalesky ('36) distinguishes two varieties of lipsomes in the cortex of the guinea pig. The smaller ones, which he calls microliposomes, are 0.4 to 2.5 microns in diameter. The larger are known as macroliposomes and are from 3.5 to 20 microns in diameter. The macroliposomes may be intercellular although usually they are intracellular. They do not stain as deeply with osmic acid as do the microliposomes and are often dissolved out completely with alcoholic dehydration and infiltration with paraffin. A chemical difference between the two is evident. The macroliposomes are confined chiefly to the fasciculata zone; the microliposomes have a much wider distribution.

**Experimental modifications of the histological structure of the adrenal cortex.**—Investigations on the experimental modifications of the mammalian adrenal cortex have been numerous in recent years. Naturally, most of this investigation has centered upon the gland with the purpose of determining its varied functions. The problem of the exact role of the adrenal cortex has been attacked from many angles. In the space of this paper it is impossible to report on all of this investigation. We wish to point out some of the most striking work recently performed on the adrenal cortex and to indicate the main conclusions to be drawn from this work. In spite of contradictory points here and there, there is much of a definite character that seems to be well established.

The experimental modifications of the cortex has mainly involved two methods: (1) the effects produced in the cortex by the removal of

other endocrine glands and (2) the effects produced by the injection of substances such as hormones and toxins as well as other things.

Considering the interrelations of the endocrine glands, it is quite logical that much of our knowledge of the adrenal cortex has arisen from the removal of other glands, or glandectomy, noting the effects of the removal. Hypophysectomy has been one of the most common. There is almost general agreement that such operations lead to marked atrophy of the adrenal cortex. Reese and Moon ('38) have shown that many changes in the cortex begin a few hours after this operation. This is especially the case with the Golgi apparatus which remains in a shrunken form for 300 to 400 days after hypophysectomy. Cutuly ('36), working on the same animals, rats, observed that the greatest atrophy occurred 30 days after the operation. Crooke and Gilmour ('38) observed in immature rats that this degeneration is most evident in the reticular zone where the cells were reduced in number and there was a marked infiltration of lymphocytes as well as an increased pigmentation. The lipoid content in the same zone was also reduced.

Simmons and Whitehead ('37) reveal that in cases of unilateral adrenalectomy the cortex of the unmolested adrenal shows a decrease in the fat density in the outer zone of the gland but an increase in the inner part. As regards gonadectomy and its effects on the cortex, Zalesky ('36) found that the operation performed before sexual maturity induces no permanent hypertrophy or atrophy in the guinea pig adrenal but does cause some increase in the lipoids of the cortex.

It has long been known that animals dying from adrenal deficiency show symptoms similar to those in severe toxemia. Moreover, animals which survive double adrenalectomy are more susceptible to various toxins than are the normal controls. Deanesly ('31) found that the injection of certain bacilli, morphine, and other toxins appears to have the same effect on the cortical zones as that of thyroxin. These changes are associated with enlargement of the cortex and a considerable decrease in the cortical fats and lipoids. Schmidt and Schmidt ('37) discovered that ingestion of thyroxin resulted in an increase of mitotic activity, but in this case the scene of the mitoses was confined chiefly to the *zona fasciculata* instead of being also in the *zona glomerulosa* as was the case with control animals.

A marked atrophy of the cortex is produced when large amounts of cortin are administered to an animal. Ingle ('38) points out that, when this is injected into a normal animal, the adrenal cortex decreases. If the hypophysis has been removed, however, and the animal receives the adrenotropic hormone, there is no apparent effect of cortin on the adrenal cortex. Reese and Moon ('38) state that the injection of the adrenotropic hormone causes hypertrophy of the Golgi apparatus in the cortex of the normal male rat. When this hormone is injected into the hypophysectomized animal, however, the hormone not only maintains the normal appearance of the apparatus but also causes it to hypertrophy. Many other investigators confirm this.

In many of these experimental modifications one thing is quite noticeable. Of the three zones, the cells of the reticularis are unusually sensitive to diseases and toxins. This may be due to the fact that these

cells are senescent or dying and receive an enormous blood supply which brings them into contact with a large quantity of the noxious agencies.

**A preliminary account of the authors' work on the adrenal cortex of the albino mouse.**—Our own work has centered mainly upon one or two aspects of the physiological cytology of the adrenal cortex, especially upon cytoplasmic organelles. The theory has long been known in biology that there is a relation between certain cytoplasmic inclusions and the functions of the cell. Most of the attention in this respect has been directed to the organs of exocrine secretion where it has been possible to stimulate them to their optimum rate. In this way it is possible to follow the cells in their secretory cycles.

Only recently have the organs of endocrine secretions been so studied since little has been known of their secretory rate, their intrinsic secretory cycle, methods of bringing about optimum secretory activity, and their secretory products. But with the recent purification and the fairly accurate assay of endocrine material, the authors are endeavoring to repeat, using the adrenal cortex, the work of earlier exocrine cytologists.

The mouse adrenal was chosen as the optimum tissue, owing to its small size and the ease of its fixation in the entire condition. Cell structures are very sensitive to manipulation, and fixation of the much larger adrenals of the common laboratory animals is not feasible for most of this cytological work.

Experimental animals (adult albino mice) were given one Collip rat unit of the adrenotropic factor. The substance used for this was Ayerst and McKenna's growth complex, which contains growth substance as well as the adrenotropic factor. Since adult animals were used throughout, the growth factor can be ruled out as affecting our results. Controls were given a similar volume of standard saline solution.

Our results, to date, show, among other things, that the adrenal weights of the mouse bear no absolute constant relation to the body weight but may vary in the normal animal from 0.01% to 0.035% of the body weight. In all cases of experimental animals, the weights increased up to more than 0.06% by the fifth day following administration of the hormone. The average actual weight of adrenal material in the normal mouse is 5 mg. Actual weights increased in some cases as much as three times the normal by the fifth day after injection and in all cases had at least doubled by that time.

Gross histological examination reveals that the cortex had increased greatly in width in relation to the width of the entire gland. The increase seems to be confined mainly to the *zona reticularis* and *zona fasciculata*.[1]

Weight increases seem to be due to this augmented activity as well as to the appearance of more lipoids in the gland.

The glands were fixed according to the formalin-bichromate and other techniques, and observations to date reveal that there is an in-

[1]Work on this point, using colchicine to determine the mitotic index of these regions, is being done at the Biological Laboratories, Harvard University, by the junior author.

crease in mitochondria in the reticularis and fasciculata zones, that there is an increase in the rod-like forms of mitochondria, that the granular forms appear to be swelled, and that the mitochondria is seen for the most part on the capillary side of the cell.

Further work to extend these preliminary findings is under way.

**Conclusion.**—At the present time we may briefly conclude that the mammalian adrenal cortex is a gland of continuous change as regards its histological and cytological make-up. It may be considered a complex of cells, which in their migration from capsule to medulla undergo a progressive change of cell types more or less localized into different zones. These cell types reveal differences in cytological details, as lipoids, cell inclusions of various kinds, size relations, etc., which are correlated with the stages in the life history of the cell. Moreover, the experimental modifications induced by such agencies as injections of toxins, and hormones, and by glandectomy are manifested chiefly in an accelerated or retarded differentiation of these cell relations and characters. But the picture is far from complete, and there are yet lacking many details which must be filled in before we can arrive at a sound morphological and functional interpretation of the adrenal cortex.

## References

Crooke, A. C., and J. R. Gilmour, 1938. A description of the effect of hypophysectomy on the growing rat with the resulting histological changes in the adrenal and thyroid glands and the testicles. Journ. Path. and Bact. **47**:525-544.

Cutuly, E., 1936. Quantitative study of the adrenals of hypophysectomized rats. Anat. Rec. **66**:119-122.

Deanesly, R., 1931. The histology of adrenal enlargement under expermiental conditions. Amer. Journ. Anat. **47**.

Hoerr, N., 1931. The cells of the suprarenal cortex in the guinea pig. Their reaction to injury and their replacement. Amer. Journ. Anat. **48**.

Howard E., 1938. The representation of the adrenal X zone in rats, in the light of observations on X zone variability in mice. Amer. Journ. Anat. **62**:351-367.

Howard, E., 1939. Effects of castration on the seminal vesicles as influenced by age, considered in relation to the degree of development of the adrenal X zone. Amer. Journ. Anat. **65**:105-150.

Ingle, D. J., 1938. The effects of administering large amounts of cortin on the adrenal cortices of normal and hypophysectomized rats. Amer. Journ. Physiol. **124**:369-371.

Reese, J. D., and H. D. Moon, 1933. The Golgi apparatus of the cells of the adrenal cortex after hypophysectomy and on the administration of the adrenocorticotropic hormone. Anat. Rec. **70**:543-556.

Schmidt, I. G., and L. H. Schmidt, 1938. Variations in the structure of adrenals and thyroids produced by thyroxine and high environmental temperatures. Endocrin. **23**:559-565.

Simmons, H. T., and R. Whitehead, 1937. Fatty changes in the adrenal cortex of guinea pigs after unilateral adrenalectomy. Journ. Path. and Bact. **45**:441-446.

Zalesky, M., 1936. Effects of prepuberal gonadectomy on the adrenal gland of the guinea pig. Anat. Rec. **65**:467-483.

# A Table for the Normal Development of *Rana pipiens*[1]

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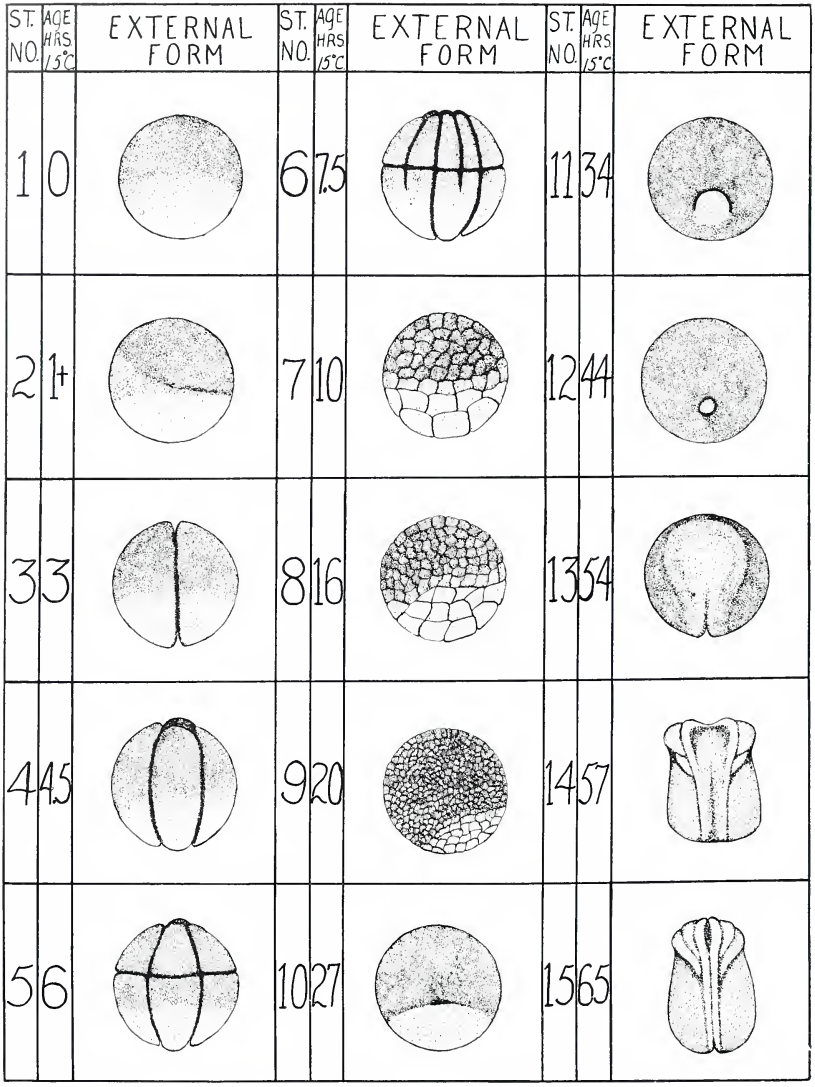
In 1918 Harrison prepared a series of arbitrary stages in the normal development of *Amblystoma punctatum* which has never been completely published. Drawings of some of the stages have been included in his papers and those of his students, who frequently refer to the series. In fact, in the later papers the drawings are no longer included since the stages have become well known. There are at least forty-six stages in this series, but there is no attempt to correlate the age of the embryo and the stage and no reference to the temperature at which development took place. In 1937 Pollister and Moore published a chart for the normal development of the frog, *Rana sylvatica*. This chart differs from the Amblystoma series by having only 23 stages which are correlated with age, temperature of development, and size in the older stages. These stages are also arbitrary but mark rather easily determined steps in development.

The usefulness of such a series or chart is shown by the frequent reference to the one of Amblystoma. The value of similar charts for anurans used in experimental embryology is threefold. First, the charts would place in the literature standard series of developmental stages for reference. Second, they would simplify the description of experimental results since it would no longer be necessary to include detailed diagrams and descriptions of the stages used. Third, they would reduce the necessity for large control groups since the normal stages are already known. This paper presents such a chart for the normal development of *Rana pipiens*.

*Rana pipiens* lays in the vicinity of Bloomington, Indiana, from about March 1 until April 15. Most of the eggs used for this study were collected from ponds around Bloomington, brought into the laboratory, and placed in a dark room with a constant temperature of 15° C. The earliest stages were secured from eggs laid in the laboratory and supplied to me from other experiments. These eggs were placed under the same conditions as those collected from the ponds and showed no differences in development.

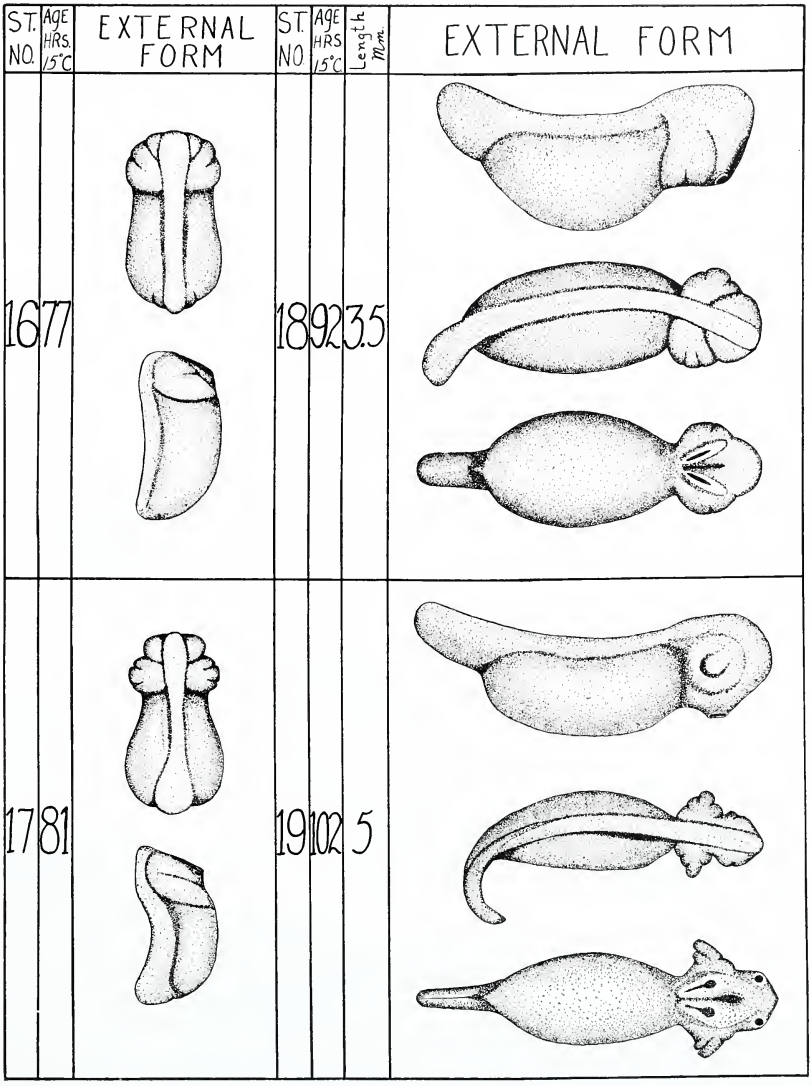
These eggs for the earliest stages were secured by pituitary injection of the adults, using the method of Rugh ('34). Rugh found that ovulation can be induced in *Rana pipiens* at any season of the year by the injection into the body cavity of whole or macerated frog pituitaries. He found that the most effective method was to inject two female pituitaries daily. This resulted in ovulation on the second to fourth day. If fertilization was desired, amplexus could be induced by pituitary injection of both the male and female, or the eggs could be stripped from the uterus into a sperm suspension prepared from macerated testes.

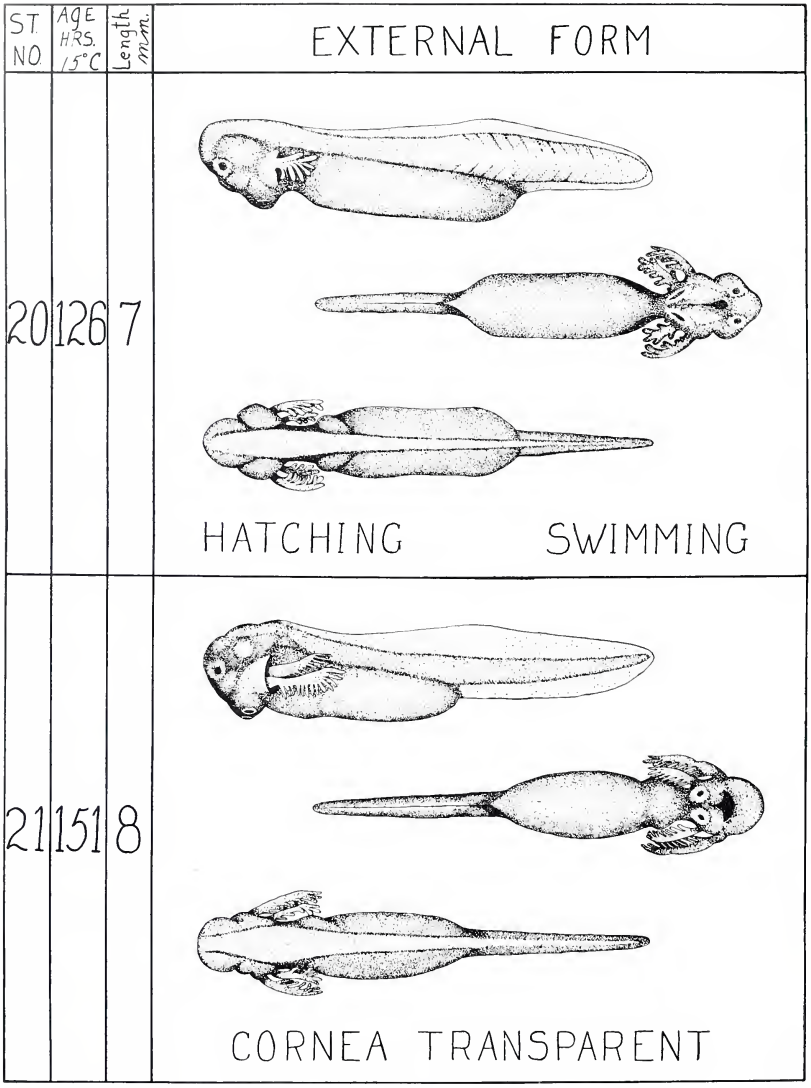
[1]This paper is based on a thesis submitted in partial fulfillment of the requirements for the A. M. degree in zoology. Contribution No. 283.




Every two hours, after the 16-celled stage, the developing eggs were studied and sketched from the live specimens. At the same time 20 to 40 eggs were fixed in Tellyesnicky's fluid and preserved in 5% formalin. These preserved eggs verified the sketches and formed the basis for the drawings of the stages selected. In each case the drawings are of individuals average in size and extent of development for the group. The stages figured and described correspond as exactly as possible to the ones figured and described by Pollister and Moore for *Rana*

*sylvatica*. This has been done for two reasons: to prevent a confusion of stages in the literature and to make a comparison of the species possible. The stages are designated by the external morphology and the age in hours after laying. For the earlier stages the number of cells, relative size of the cells, or development of the neural tube forms an adequate basis for determination. For the later stages, however, several factors, such as the transparency of the cornea and epidermis, elongation of the body, growth of the external gills, and coiling of the gut are helpful in determining the stage designated. Certain physio-






logical features of development, such as the beginning of muscular movement and of swimming and spontaneous hatching, have been used as stage markers.

### Description of Stages of *Rana pipiens*

In the following, the numbers refer to figures 1 to 23.

1. The unfertilized egg.
2. Gray crescent formed.

3-6. Early cleavage stages.

7-9. Stages in cell multiplication. The relative size of the animal and the vegetal hemisphere cells form the best criterion for determination of these stages.

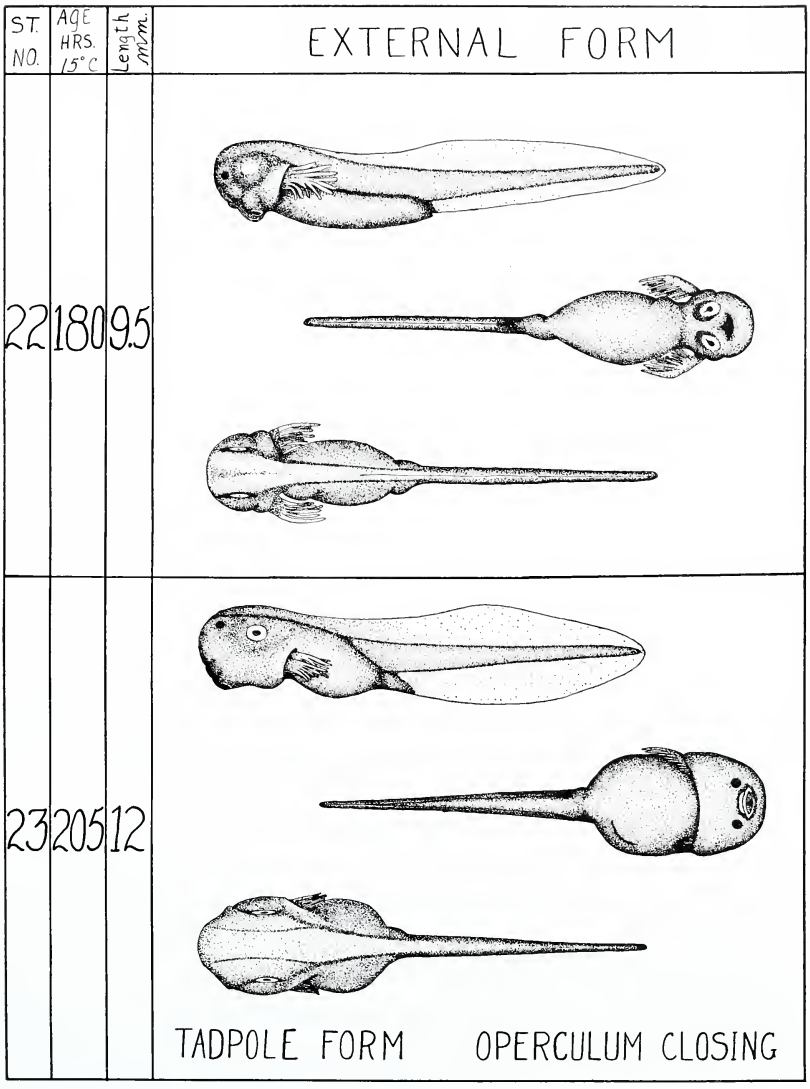
10. Appearance of the dorsal lip of the blastopore.

11. Blastopore almost semi-circular.

12. Blastopore complete, the late yolk plug stage.

13. Neural plate stage.

14. Neural folds formed.



15. Beginning of the closure of the neural tube, also the beginning of the elongation of the embryo.

16. Neural tube completely closed.

17. Beginning of the tail bud. When this stage is viewed laterally, the tail is seen marked off by a notch.

18. Capable of simple lateral movement when stimulated. There is also an indication of the division to form the gills. First distinct curvature of the body.

19. Tail equals one-third of the body length, the division of the gills is becoming definite. The embryo can be hatched by vigorous shaking.

20. Spontaneous hatching occurs in this stage, capable of simple swimming movements when disturbed. The gills are well formed. Tail equals one-half the body length. Epidermis along edges of tail becoming transparent.

21. The cornea is becoming transparent. The fold of the operculum is beginning to form. Tail almost the length of the body.

22. Trunk asymetrical when viewed from dorsal side due to coiling of intestine. Operculum well formed, tail longer than the body. Epidermis of tail transparent.

23. The embryo assumes the tadpole form. It shows active spontaneous swimming. Horny larval teeth are formed. The posterior limb bud is identifiable. The operculum is closing over the gills. Tail three times the length of body. Epidermis transparent so that the gut is visible.

## Comparison of the Species

The description of the stages here given is very similar to that given by Pollister and Moore, but this would follow since the stages are made to correspond. However, there are some differences found between *R. pipiens* and *R. sylvatica*. The most noticeable difference is in the gills and operculum. In *R. pipiens* the definite formation of the gills begins about the middle of stage 19. The operculum begins to form in stage 21 and is practically closed by stage 23. In fact, in some embryos of the same age the operculum is completely closed. In *R. sylvatica* the gills begin to form a little later and the operculum is beginning to form in stage 23. In other ways the species are very similar. But however slight the differences may be, this shows further than generalizations for one species cannot be made on the basis of another one even though they are closely related.

## Bibliography

Harrison, R. G., 1918. Experiments on the development of the fore-limb of Amblystoma. Journ. Exper. Zool. 25:413.

Harrison, R. G., 1925. The development of the balancer in Amblystoma. Journ. Exper. Zool. 41:349.

Pollister, A. W., and J. A. Moore, 1937. Tables for the normal development of *Rana sylvatica*. Anat. Rec. 68:489.

Rugh, Roberts, 1934. Induced ovulation and artificial fertilization in the frog. Biol. Bull. 66:22.

Rugh, Roberts, 1935. Ovulation in the frog. Pituitary relations in induced ovulation. Journ. Exper. Zool. 71:149.

# Radiation of *Drosophila melanogaster* With Low-Intensity Ultra-Violet Light for One Complete Generation. III. Effect on Crossing-Over in the Second Chromosome of the Male.

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## Introduction

Crossing-over in the male of *Drosophila melanogaster* formerly was supposed never to occur, but recent investigations have shown that it occasionally happens, particularly upon treatment with x-rays and heat. As yet, however, no literature has been found concerning the effect of ultra-violet light on this process.

The experiments here reported were undertaken to determine the effects upon crossing-over in the male of prolonged radiation with low-intensity ultra-violet light.

## Review of Literature

Morgan (1912) found no crossing-over in the males of Drosophila between the black and vestigial loci. He (Morgan 1914) also pointed out that the $F_2$ generation contains no double recessives when one recessive enters from each $P_1$ parent. This he considered additional evidence of no crossing-over in the male.

Muller (1916) reported a case of spontaneous crossing-over in which all of the mature germ cells of a single male Drosophila were affected. Thus, all of the backcross offspring showed crossing-over.

Bridges and Morgan (1919) found a single crossover among the offspring of Star speck/purple speck males.

From the backcross of a single male *D. simulans* Sturtevant (1929) found one crossover between scarlet and peach among the 184 offspring.

In the control cultures of a Drosophila experiment by Patterson and Suche (1934) the frequency of crossovers was one to 8,239.

Kikkawa (1935) studied crossing-over in the male of *Drosophila virilis*. He performed an experiment continuous through ten generations and found three exceptional flies in a population of 38,598. He concluded that spontaneous crossing-over does occur in the male of *D. virilis*, though the frequency is very low.

Philip (1935) found the rate of double crossing-over and inverted crossing-over between the X- and Y-chromosome in the male Drosophila to be about one in 3,000.

These cases of crossing-over are the seven exceptions in which crossing-over of a spontaneous nature has been reported in the literature of Drosophila males (Whittinghill, 1937).

Friesen (1933) X-radiated males which were heterozygous for second or third chromosome characters. These were backcrossed, and 22 crossovers were obtained among a progeny of 561. He established the fact that crossing-over in males occurred in the central region of the

chromosome—in the same region where crossing-over is increased by X-radiation of females. He believed that there is an identical mechanism of crossing-over in both sexes.

Patterson and Suche (1934) found 77 crossovers in a population of 8,371 flies after exposure of heterozygous male parents in the larval stage to X-radiation. They concluded that X-radiation induced crossing-over in the male when applied to immature germ cells containing the diploid number of chromosomes.

Shull and Whittinghill (1934), working with heat, produced crossing-over in the male of Drosophila. They found three crossovers in the third chromosome of treated males among a population of 182 flies.

Philip (1934) investigated crossing-over between X- and Y-chromosomes during normal spermatogenesis and obtained three exceptional flies among a population of 997. The probability of mutations in accounting for these exceptions was eliminated by their frequency.

Friesen (1937) in further research on second and third chromosomes of X-radiated males found no effect of stock on crossing-over in males. In studying the effect of suppressors of the inversion type on crossing-over, he concluded that inversions were more feeble suppressors of crossing-over in males than in females.

Whittinghill (1937) induced crossing-over in Drosophila males by a temperature of 35° C. applied during the larval period.

Rifenburgh (1935) obtained crossing-over in the male between the black and vestigial loci following ultra-violet radiation of young larvae.

## Methods

The source of the ultra-violet light for these experiments was a General Electric sun lamp (S2 Model K). Matings to be irradiated were made in 100 cc. beakers which were filled nearly to the top with Purdue culture medium (Rifenburgh, 1933). To prevent the medium from shrinking away from the sides of the beakers, water was added each day. Thus, the flies could not lay eggs below the surface of the medium where they might be shielded from the radiation. Both control cultures and experimental cultures were covered with cellophane. In addition, each control culture was shielded with a glass Petri plate presumably impervious to ultra-violet rays. A small electric fan was used to prevent an increase of temperature under the lamp. Room temperature was maintained at approximately 25° C. throughout the experiments.

In the first three experiments, wild-type males were mated to virgin b vg bw females. In the fourth and fifth experiments, wild-type males were mated to al b vg bw females. Parents for both treated matings and control matings were taken from the same stock cultures in order to insure identical heredity as nearly as possible. As soon as pupae appeared, the parents were removed from the beakers. The offspring were irradiated until their emergence from the pupa cases. Emergent flies $\left(\frac{\text{b vg bw}}{+} \text{ or } \frac{\text{al b vg bw}}{+}\right)$ were removed daily from the radiation, and the males backcrossed in ordinary culture bottles (in the room away from the lamp) to females of the recessive type. Each male was

TABLE I.—Emergence Record of Backcrosses (Second and Third Regions)

| | Experimentals | | | Controls Under Lamp | | | | | Controls Not Under Lamp | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Number of Experiment..... | II | IV | Total II & IV | I | II | IV | VA | Totals I, II, IV & VA | III | VB | Total III & VB |
| Parental Types..... | 16,010 | 4,293 | 20,303 | 11,514 | 9,403 | 5,470 | 9,228 | 35,615 | 23,712 | 9,179 | 32,891 |
| Cross-overs b to vg..... | 88 | 58 | 146 | 12 | 31 | 22 | 18 | 83 | 76 | ..... | 76 |
| Cross-overs vg to bw..... | 20 | ..... | 20 | 1 | ..... | 10 | ..... | 11 | ..... | ..... | ..... |
| Totals..... | 16,118 | 4,351 | 20,469 | 11,527 | 9,434 | 5,502 | 9,247 | 35,710 | 23,788 | 9,179 | 32,967 |

mated to a group (3 or 4) of virgin females. On the following day each male was removed from the females and transferred to a new group of virgin females. This process was repeated every day with other groups until each male had been mated successively to five groups of females. Each group of females was placed successively in several (3 to 5) culture bottles and allowed to remain three days in each bottle. This procedure resulted in a relatively large number of cultures and an enormous progeny from each tested male.

In Experiment I a distance of 47 inches from the lower end of the bulb to the top of the medium was maintained. Twelve treated cultures and twelve control cultures were used. In starting these cultures, the flies were etherized for convenience in handling, placed in the beakers, and immediately subjected to the ultra-violet rays. Eight emergent $F_1$ treated males and eight emergent $F_1$ control males were backcrossed individually to b vg bw females with a total of 400 backcross cultures. However, the experimental cultures were ruined by accident; therefore, only the 200 control cultures are included in the report.

In Experiment II the distance was 52 inches. Eighteen treated cultures and six control cultures were used. Males and females were placed in the beakers and allowed to recover from etherization for eight hours before exposure to radiation. Of the emergent $F_1$ progeny, 25 treated males and 11 control males were used for back-crossing. There was a total of 430 backcross cultures.

In order to investigate crossing-over of a spontaneous nature, a third series of controls was run with the same procedure and technique as in the controls of Experiment II, except that controls III were not placed under the ultra-violet lamp and were not subject to any radiation from it.

In Experiment IV the character aristaless was added to black vestigial brown, giving more complete coverage of the chromosome. The procedure and technique was the same as in the preceding experiments, except that the distance from bulb to medium was increased to 52½ inches. A total of 256 backcross cultures was obtained by back-crossing thirteen emergent $F_1$ treated males and ten emergent $F_1$ control males (heterozygous for aristaless black vestigial brown) to virgin al b vg bw females.

In Experiment V two control populations were obtained. One set (VA) was run under the lamp; the second set (VB) was placed in the room away from the influence of the radiation. Twelve emergent $F_1$ males were tested from each set, giving a total of 263 backcross cultures.

In all the experiments reported in this paper, a grand total of 105 males were tested in 1,217 backcross cultures. These males produced a population of 89.146 offspring.

## Results

Emergence tabulations for the backcross are shown in Table I. Parental and single crossover classes are represented, but there is no instance of double crossing-over.

Cross-over between the aristaless and black loci occurred but once, a single exceptional fly (a black vestigial brown female) being

TABLE II.—The Percentage of Recombination Between Black and Vestigial Loci

| Experiment Number | Experimentals | | | Controls | | | Difference in % | D / P. E. (diff) |
|---|---|---|---|---|---|---|---|---|
| | No. ♂♂ Tested | Population | Recombination % b to vg | No. ♂♂ Tested | Population | Recombination % b to vg | | |
| I | | | | 8 | 11,527 | .104 ±.0199 | | |
| II | 25 | 16,118 | .546±.039 | 11 | 9,434 | .3286±.0398 | .2174±.0557 | 3.9 |
| III | | | | 14 | 23,788 | .3195±.0236 | | |
| IV | 13 | 4,351 | 1.333±.117 | 10 | 5,502 | .3998±.0483 | .9302±.1265 | 7.35 |
| VA | | | | 12 | 9,247 | .195 ±.03095 | | |
| VB | | | | 12 | 9,179 | | | |
| II & IV | 38 | 20,460 | .713±.0397 | | | | | |
| I, II, IV & VA | | | | 41 | 35,710 | .232±.0171 | .001±.025 | .04 |
| III & VB | | | | 26 | 32,967 | .231±.01779 | | |

found among the VA (under the lamp) controls. This one recombination occurred among a total radiated and control population of 28,459.

Percentages of recombination between the black and vestigial *loci* and also between the vestigial and brown loci are indicated in Tables II and III, respectively. Although crossing-over occurred in both regions among controls, there is a significantly higher percentage of recombination between these loci in the radiated cultures. Also, crossing-over is more frequent in the region of the spindle-fiber (between the black and vestigial loci than in either remote region.

Of the 38 treated males, nine (23.7%) showed crossing-over. Five (17%) of the 53 control males showed crossing-over. The total percentage of recombination is given in Table IV. The number of crossovers for each region produced by each of these males is shown in Table V. It is significant that crossovers did not appear in all cultures. Usually, several crossovers were found among the offspring of any one male or else crossing-over was completely absent (only four males of the 24 showing crossing-over produced less than three crossovers each.)

In Table VI the number of crossovers is given according to the age of the male at the time of mating. In the treated cultures and in controls as well, the number of crossovers produced varied with the age of the male, the greatest number appearing as a result of matings when the males were from two to seven days of age.

A total of 337 crossovers were found among the 89,146 backcross offspring. These were distributed as follows: 166 from experimental cultures, 95 from controls under the lamp, and 76 from controls not under the lamp.

## Discussion

Crossing-over occurred in both radiated and control males. Treated males produced .811 ± .0423% of recombination in comparison with .246 ± .0127% from the control males. This gives a difference of .565 ± .0442%, which is certainly significant, it being 12.8 times its probable error.

The rate of recombination, not only in the experimental cultures but also in the controls, is high compared with records in the literature. Spontaneous crossing-over in males has been reported before in chance findings (Muller, 1916, Bridges and Morgan, 1919, Sturtevant, 1929) and also in researches directed at this possibility. The frequency was one in 3,000 (Philip, 1935), one in 8,239 (Patterson and Suche, 1934), and in another species, *D. virilis*, three in 38,598 (Kikkawa, 1933). These records are much lower than the frequency found in the work reported in this paper, which was 337 in 89,146 or about one in 264. The controls gave one in 404, and the radiated males produced one crossover for each 123 offspring.

Crossing-over in the left end of the second chromosome is so rare (one in 28,279) that it almost never occurs; nevertheless, the one instance shows that it is not impossible here. It is not known, however, just how far from the central region it happened since there was no marker between aristaless and black.

TABLE III.—The Percentage of Recombination Between Vestigial and Brown Loci

| Experiment No. | Experimentals | | | Controls | | | Difference in % | D / P. E. (diff) |
|---|---|---|---|---|---|---|---|---|
| | No ♂♂ Tested | Population | Recombination % vg to bw | No. ♂♂ Tested | Population | Recombination % vg to bw | | |
| I | | | | 8 | 11,527 | .0087 ± .00586 | | |
| II | 25 | 16,118 | .1241 ± .0187 | 11 | 9,434 | | | |
| III | | | | 14 | 23,788 | | | |
| IV | 13 | 4,351 | | 10 | 5,502 | .182 ± .03876 | | |
| VA | | | | 12 | 9,247 | | | |
| VB | | | | 12 | 9,179 | | | |
| II & IV | 38 | 20,469 | .0977 ± .01473 | | | | | |
| I, II, IV & VA | | | | 41 | 35,710 | .0308 ± .00623 | .0308 ± .0062 | 4.9 |
| III & VB | | | | 26 | 32,967 | | | |

TABLE IV.—Total Percentage of Recombination

| | Experimentals | Controls | Difference | $\frac{D}{P.\ E.\ (diff)}$ |
|---|---|---|---|---|
| Number of Males Tested | 38 | 86 | ..... | ..... |
| Population | 20,469 | 69,030 | ..... | ..... |
| Recombination % al to b | ..... | .0108 ± .00728 | ..... | ..... |
| Recombination % b to vg | .713 ± .0397 | .2303 ± .01228 | .4827 ± .0416 | 11.6 |
| Recombination % vg to bw | .0977 ± .01473 | .0159 ± .00318 | .0818 ± .0151 | 5.42 |
| Total % of Recombination | .811 ± .0423 | .246 ± .0127 | .565 ± .0442 | 12.8 |

Grand Total % of Recombination, Experimentals and Controls Combined, .378 ± .0138

TABLE V.—Crossovers by Males According to Region of Chromosome

al to b—1 b to vg—2 vg to bw—3

| Male Number | Experimentals | | | | | | | | | | Controls Under Lamp | | | | | | | | | Controls Not Under Lamp | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Exp. II | | | | | | | | Exp. IV | Total Exp. | Exp. I | | | Exp. II | | Exp. IV | | Exp. VA | | Total | Exp. III | | | | | | Total |
| Region Number | 2X | 4X | 7X | 10X | 14X | 15X | 16X | 18X | 10X | | 4C | 6C | 10C | 2C | 5C | 5C | 10C | 2XC | 12XC | | 1C | 2C | 7C | 11C | 12C | 13C | |
| 1 | .... | .... | .... | .... | .... | .... | .... | .... | ..... | ..... | .... | .... | .... | .... | .... | .... | .... | .... | 1 | 1 | .... | .... | .... | .... | .... | .... | ..... |
| 2 | 1 | 3 | 16 | 6 | 22 | 11 | 20 | 9 | 58 | 146 | 3 | 3 | 6 | 11 | 20 | .... | 22 | 18 | ..... | 83 | 7 | 1 | 10 | 16 | 41 | 1 | 76 |
| 3 | .... | 7 | 6 | .... | .... | 2 | 4 | 1 | ..... | 20 | .... | .... | 1 | .... | .... | 10 | .... | .... | ..... | 11 | .... | .... | .... | .... | .... | .... | ..... |
| Totals | 1 | 10 | 22 | 6 | 22 | 13 | 24 | 10 | 58 | 166 | 3 | 3 | 7 | 11 | 20 | 10 | 22 | 18 | 1 | 95 | 7 | 1 | 10 | 16 | 41 | 1 | 76 |

Total Population Involved.....20,469.....35,710.....32,967

Grand Total of All Crossovers..... 337

Grand Total Population.....89,146

Crossing-over occurred most frequently in the control region between the black and vestigial loci which includes the spindle-fiber attachment. More than nine-tenths of the crossing-over occurred in this region, and less than one-tenth in the region toward the right end of the chromosome (vestigial to brown), which covers a map distance about twice as great as the inclusive region.

In several males, crossing-over was not limited to a single region. With one exception (male 12XC), it never occurred in a remote region unless it also occurred in the inclusive region. Among males showing crossing-over in two regions, the frequency was higher for each male in the inclusive region with one exception (male 4X). These results agree with those of Whittinghill (1937) and Friesen (1933), who found most of the crossing-over in the inclusive region. However, occurrence in several males of crossing-over in two regions differs from the results of these two investigators who found it to be localized in one region only. It seems that Whittinghill was not justified in concluding that crossing-over is limited to only one region of the chromosome in any male. Perhaps he would not have reached such a conclusion had not the population in his experiments been so small (some 3,000 flies.)

The region most susceptible to modification of frequency rate (due to ultra-violet radiation) was a region (vg to bw) remote from the spindle-fiber attachment. The rate of crossing-over was increased more than six times in this region after treatment with ultra-violet light, whereas the rate was only slightly more than tripled in the inclusive region.

In regard to the two types of controls—*i.e.*, under the lamp or not under the lamp—the rate for the first region was almost identical (.232 ± .071% and .231 ± .0178%), but for the right limb of the chromosome, it was significantly different (.0308 ± .0062% and zero). However, in view of the fact that there was no significant change in the inclusive region, it is suggested that perhaps the cause of the difference may not be the permeability of the glass cover to radiation but some other factor such as genes, or effect of stock, as it is sometimes called.

Effect of stock is suggested also by the fact that only certain males showed crossing-over (24 out of 105 tested), by the variation in number of exceptional offspring from such males (1 to 58), and by the rather large average number of such exceptional offspring per male (14).

The results of Friesen's work (1937) show no effect of stock, but here again the data seem insufficient owing to small populations.

Crossing-over in the male may be much the same process as in the female since ultra-violet radiation increases its rate in both sexes (Rifenburgh, 1935, as well as experiments here reported). However, its relative rate in the various parts of the chromosome differs in the sexes since in the male it is grouped around the spindle-fiber attachment—at least in the second chromosome.

## Summary

1. More crossing-over occurred in radiated individuals than among controls. The difference was statistically significant, it being nearly 13 times its probable error.

TABLE VI.—Crossovers by Males According to Age at Mating

| Male Number | Experimentals | | | | | | | | | | Controls Under Lamp | | | | | | | | | | Controls Not Under Lamp | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Exp. II | | | | | | | | Exp. IV | Total | Exp. I | | | Exp. II | | Exp. IV | | Exp. VA | | Total | Exp. III | | | | | | Total |
| Age at Mating | 2X | 4X | 7X | 10X | 14X | 15X | 16X | 18X | 10X | | 4C | 6C | 10C | 2C | 5C | 5C | 10C | 2XC | 12XC | | 1C | 2C | 7C | 11C | 12C | 13C | |
| 1 Day | | | | | | | 4 | | | 4 | 1 | 2 | | | 2 | | | 2 | | 7 | | | | | | | |
| 2 Days | | 1 | 11 | | 2 | 4 | 6 | 9 | | 33 | 1 | 1 | 4 | 11 | 4 | | 20 | 1 | | 42 | | | | 4 | 5 | | 9 |
| 3 Days | 1 | 8 | 9 | 6 | 16 | 1 | 14 | 1 | | 56 | 1 | | 1 | | 9 | 1 | | 1 | 1 | 14 | | | | 12 | 13 | | 25 |
| 4 Days | | 1 | 2 | | 4 | | | | 10 | 17 | | | 1 | | 5 | 2 | | | | 8 | 1 | | | | 17 | 1 | 19 |
| 5 Days | | | | | | 8 | | | 8 | 16 | | | 1 | | | | | 4 | | 5 | 3 | | | | | | 3 |
| 6 Days | | | | | | | | | 19 | 19 | | | | | | | 2 | | | 2 | 3 | 1 | 1 | | | | 5 |
| 7 Days | | | | | | | | | 12 | 12 | | | | | | 4 | | 5 | | 9 | | | | | | | |
| 8 Days | | | | | | | | | 9 | 9 | | | | | | | | 5 | | 5 | | | | | | | |
| 9 Days | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 10 Days | | | | | | | | | | | | | | | | 3 | | | | 3 | | | | | 6 | | 6 |
| 11 Days | | | | | | | | | | | | | | | | | | | | | | | 9 | | | | 9 |
| Totals | 1 | 10 | 22 | 6 | 22 | 13 | 24 | 10 | 58 | 166 | 3 | 3 | 7 | 11 | 20 | 10 | 22 | 18 | 1 | 95 | 7 | 1 | 10 | 16 | 41 | 1 | 76 |

Grand Total of All Crossovers ..... 337

2. In most males, crossing-over was limited to the region including the spindle-fiber attachment.
3. In several males, crossing-over occurred in two regions.
4. Modification of crossover frequency was highest in a region of the chromosome remote from the spindle-fiber attachment.
5. Crossing-over in the second chromosome of the male differs from that in the female in respect to relative rates in different regions.
6. These results agree with those of certain other investigators who, working with various types of radiation, found crossing-over in the male concentrated in the region of the spindle-fiber attachment.
7. These results do not agree with those of certain other investigators who found crossing-over in a given male to occur in one region only.
8. These results disagree with those which led certain investigators to believe that crossover frequency in the male is more easily modified in the region including the spindle-fiber attachment than in remote regions.
9. Effect of stock is suggested as a probable factor in frequency of crossing-over.

## Bibliography

Bridges, C. B., 1932. Recombination and crossing-over. Amer. Nat. **66**.

Bridges, C. B., and T. H. Morgan, 1919. The second chromosome group of mutant characters. Carnegie Inst. Wash. Publ. **278**:123-304.

Friesen, Heinrich, 1933. Artificially induced crossing-over in males of *Drosophila melanogaster*. Sci. **78**:513-514.

Friesen, Heinrich, 1937. Mechanism of crossing-over in males of *Drosophila melanogaster*. Journ. Gen. **35**.

Kikkawa, H., 1935. Crossing over in the male of *Drosophila virilis*. Cytol. **6**:190-194.

Morgan, T. H., 1912. Complete linkage in the second chromosome of the male of Drosophila. Sci. **36**:719-720.

Morgan, T. H., 1914. No crossing-over in the male of Drosophila of genes in the second and third pair of chromosomes. Biol. Bul. **26**:195-204.

Muller, H. J., 1916. The mechanism of crossing-over. Amer. Nat. **50**:193-221, 284-285.

Patterson, J. T., and Meta L. Suche, 1934. Crossing-over induced by x-rays in Drosophila males. Gen. **19**:223-237.

Philip, U., 1935. Crossing-over between the X- and Y-chromosome in Drosophila. Journ. Gen. **31**:341-352.

Rifenburgh, S. A., 1933. A new medium for Drosophila cultures. Proc. Indiana Acad. Sci. **42**:257-258.

Rifenburgh, S. A., 1935. Genetic effects of ultra-violet radiation on *Drosophila melanogaster*. Thesis. Purdue University.

Shull, A. F., and M. Whittinghill, 1934. Cross-overs in males of *Drosophila melanogaster*. Sci. **80**:103-104.

Sturtevant, A. H., 1929. The genetics of *Drosophila simulans*. Carnegie Inst. Wash. Publ. **399**:1-62.

Whittinghill, Maurice, 1937. Induced crossing-over in Drosophila males and its probable nature. Gen. **22**:114-129.

# Intestinal Parasitism in a Group of University Students

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## Introduction

During the past few years the writer has initiated studies concerning human parasite infections in Indiana, giving especial attention to the incidence of intestinal parasites as determined by laboratory diagnosis. A survey of the available literature was made (Headlee, 1937) which indicated that there were random case reports of parasite infections but that there were no valid data concerning the incidence of these infections in the general population of the state.

Subsequent to that time, laboratory examinations were made of over 1,300 persons residing in Indiana to determine the incidence of intestinal parasites, including both protozoa and helminths. The largest group examined, 1,200 persons, were patients of Longcliff State Hospital (Kmecza, 1939). Other examinations of persons included students of Purdue University and random examinations of persons in the locality of Lafayette, Indiana. A summary of the results of all these examinations of persons residing in Indiana was made by the writer (Headlee, 1939), but the group of out-of-state Purdue students was not included in that particular report. The present paper deals with the results of examinations of Purdue students as a group, including both residents of Indiana and non-resident students.

## Materials and Methods

The data presented in this paper were obtained primarily by microscopic examination of fecal specimens, by which examinations both the cysts and trophozoites and the eggs of helminths could be detected. The stool specimens were collected in cardboard containers and examined within 24 hours after collection. Both unconcentrated and centrifugalized, concentrated preparations were examined from each fecal specimen, following the procedure outlined in a previous report (Headlee, 1939). In a few instances, the data were obtained by the identification of adult helminths that had been eliminated from the bowel, subsequent stool examinations indicating that no other worms were present.

## Presentation of Data

Stools were examined from 213 students of Purdue University to determine the incidence of intestinal parasites. The stools were collected primarily through the cooperation of the Purdue University Student Health Service, but only relatively few students had visited the Health Service because of digestive complaints. Of the 213 students examined, 168 were males and 43 were females, 206 or 96.9% being between the ages 17 to 30 years, inclusive. The ages of the males ranged from 17 to 36 years; those of the females ranged from 17 to 60 years, inclusive. Of these students, 209 were from 17 states of the United States, 162 or 76.5% of the total number examined being from

Indiana and 47 or 22% of the total examined being from the 16 other states. Of the four remaining students, one was from the District of Columbia, one from Mexico, and two from Venezuela. The 162 students who were residents of Indiana were from 59 of the 92 counties of the state. Thirty-nine of these students were from Tippecanoe County, this being the largest number from any single county. Sixty-two of the 213 persons examined or 29.1% were residents of rural areas.

The species of parasites encountered and the percentage incidence of each were as follows: *Endamoeba histolytica*, 2.8; *Endamoeba coli*, 19.7; *Endolimax nana*, 30.5; *Iodamoeba bütschlii*, 1.4; *Giardia lamblia*, 2.3; *Chilomastix mesnili*, 0.5; *Ascaris lumbricoides*, 0.9; *Trichuris trichiura*, 0.9; *Necator americanus*, 0.5; *Enterobius vermicularis*, 1.9; *Hymenolepis nana*, 0.5. Further examination of the data showed that 91 individuals or 42.7% were infected with protozoa; 10 individuals or 4.7% were infected with helminths, and 4 persons or 1.9% harbored infections of both protozoa and helminths. Of the 213 students examined, 97 or 45.5% were infected with one or more species of protozoa, helminths, or both protozoa and helminths. These data are presented in detail in Table I.

## Discussion and Conclusions

Among the six students harboring infections of *Endamoeba histolytica*, only one person is recorded as having symptoms of amebic dysentery. It may be considered that the others found infected with this organism were carriers. It must not be overlooked that these individuals are a source of material for the spread of infections with this organism and that the particular strain might prove to be pathogenic for other persons infected.

Wenrich, Stabler, and Arnett (1935) reported their findings from the examination of 1,060 students of a professional school of Philadelphia, Pennsylvania, for infections with intestinal protozoa. A comparison of the data from that survey with that of the present survey is given in Table II.

These two sets of data can not readily be compared because of a difference in methods used. In the Philadelphia survey wet smears were examined as in the present survey, but concentrated preparations were not examined. In addition to the wet preparations these workers examined smears stained with iron alum-haematoxylin. This method gave results 17.7% higher for total infections than the wet preparations alone. By this method the incidence of *Endamoeba histolytica*, based on the examination of 700 persons, was raised 1.4%. Taking this into consideration, the incidence would be 2.7% for the wet smears. This compares favorably with the 2.8% obtained in the present survey. The total incidence of protozoal infections and the incidences of *Endamoeba coli*, *Endolimax nana*, and *Iodamoeba bütschlii* were higher in the present survey than those of the Philadelphia survey; the incidences of *Endamoeba histolytica*, *Dientamoeba*, *Giardia* and *Chilomastix* were lower.

The incidence of helminths was low, but we would hardly expect to find a high incidence of these parasites in a population group of the type examined. The species most frequently encountered was *Enterobius*

TABLE I.—The Incidence of Intestinal Parasites Among Students of Purdue University

| Age | 17-20 Years | | | | | | 21-30 Years | | | | | | 31- Years | | | | | | Total | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sex | M | | F | | M & F | | M | | F | | M & F | | M | | F | | M & F | | M | | F | | M & F | |
| | No. | % | No. | % | No. | % | No. | % | No. | % | No. | % | No. | % | No. | % | No. | % | No. | % | No. | % | No. | % |
| End. hist. | 2 | 2.8 | 1 | 5.9 | 3 | 3.4 | 2 | 2.2 | 1 | 3.8 | 3 | 2.6 | .... | .... | .... | .... | .... | .... | 4 | 2.4 | 2 | 4.4 | 6 | 2.8 |
| End. coli | 9 | 12.5 | 2 | 11.8 | 11 | 12.4 | 23 | 25.3 | 6 | 23.1 | 29 | 24.8 | 1 | 20.0 | 1 | 50.0 | 2 | 28.6 | 33 | 19.6 | 9 | 20.0 | 42 | 19.7 |
| Endolimax nana | 26 | 36.1 | 5 | 29.4 | 31 | 34.8 | 27 | 29.7 | 5 | 19.2 | 32 | 27.4 | 1 | 20.0 | 1 | 50.0 | 2 | 28.6 | 54 | 32.1 | 11 | 24.4 | 65 | 30.5 |
| Iodamoeba | 1 | 1.4 | .... | .... | 1 | 1.1 | 1 | 1.1 | 1 | 3.8 | 2 | 1.7 | .... | .... | .... | .... | .... | .... | 2 | 1.1 | 1 | 2.2 | 3 | 1.4 |
| Giardia | 2 | 2.8 | 1 | 5.9 | 3 | 3.4 | 2 | 2.2 | .... | .... | 2 | 1.7 | .... | .... | .... | .... | .... | .... | 4 | 2.4 | 1 | 2.2 | 5 | 2.3 |
| Chilomastix | .... | .... | 1 | 5.9 | 1 | 1.1 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 1 | 2.2 | 1 | 0.5 |
| Ascaris | 1 | 1.4 | .... | .... | 1 | 1.1 | 1 | 1.1 | .... | .... | 1 | 0.9 | .... | .... | .... | .... | .... | .... | 2 | 1.1 | .... | .... | 2 | 0.9 |
| Trichuris | 1 | 1.4 | .... | .... | 1 | 1.1 | .... | .... | 1 | 3.8 | 1 | 0.9 | .... | .... | .... | .... | .... | .... | 1 | 0.6 | 1 | 2.2 | 2 | 0.9 |
| Necator | .... | .... | .... | .... | .... | .... | 1 | 1.1 | .... | .... | 1 | 0.9 | .... | .... | .... | .... | .... | .... | 1 | 0.6 | .... | .... | 1 | 0.5 |
| Enterobius | .... | .... | 2 | 11.8 | 2 | 2.2 | 2 | 2.2 | .... | .... | 2 | 1.7 | .... | .... | .... | .... | .... | .... | 2 | 1.1 | 2 | 4.4 | 4 | 1.9 |
| Hymenolepis | .... | .... | .... | .... | .... | .... | 1 | 1.1 | .... | .... | 1 | 0.9 | .... | .... | .... | .... | .... | .... | 1 | 0.6 | .... | .... | 1 | 0.5 |
| Total infected with protozoa | 30 | 41.7 | 6 | 35.3 | 36 | 40.4 | 42 | 46.1 | 10 | 38.5 | 52 | 44.4 | 2 | 40.0 | 1 | 50.0 | 3 | 42.9 | 74 | 44.0 | 17 | 37.8 | 91 | 42.7 |
| Total infected with helminths | 2 | 2.8 | 2 | 11.8 | 4 | 4.5 | 5 | 5.5 | 1 | 3.8 | 6 | 5.1 | .... | .... | .... | .... | .... | .... | 7 | 4.2 | 3 | 6.7 | 10 | 4.7 |
| Total infected with both protozoa and helminths | 1 | 1.4 | .... | .... | 1 | 1.1 | 3 | 3.3 | .... | .... | 3 | 2.6 | .... | .... | .... | .... | .... | .... | 4 | 2.4 | .... | .... | 4 | 1.9 |
| Total infected | 31 | 43.1 | 8 | 47.1 | 39 | 43.8 | 44 | 48.4 | 11 | 42.3 | 55 | 47.0 | 2 | 40.0 | 1 | 50.0 | 3 | 42.9 | 77 | 45.8 | 20 | 44.4 | 97 | 45.5 |
| Total examined | 72 | | 17 | | 89 | | 91 | | 26 | | 117 | | 5 | | 2 | | 7 | | 168 | | 45 | | 213 | |

TABLE II.—Comparison of the Incidence of Protozoal Infections Among College Students of Two Institutions in the Temperate Region

| | Philadelphia Professional School | | Purdue University | |
|---|---|---|---|---|
| | Number | Per cent | Number | Per cent |
| Endamoeba histolytica | 43 | 4.1 | 6 | 2.8 |
| Endamoeba coli | 154 | 14.5 | 42 | 19.7 |
| Endolimax nana | 121 | 11.4 | 65 | 30.5 |
| Iodamoeba bütschlii | 11 | 1.0 | 3 | 1.4 |
| Dientamoeba fragilis | 45 | 4.3 | 0 | 0.0 |
| Giardia lamblia | 79 | 7.5 | 5 | 2.3 |
| Chilomastix mesnili | 10 | 0.94 | 1 | 0.5 |
| Total infected with protozoa | 366 | 34.5 | 91 | 42.7 |
| Number examined | 1,060 | | 213 | |

*vermicularis*. No doubt the incidence of this parasite would have been considerably higher if perianal scrapings had been examined.

Although the incidence of pathogenic species was relatively low, it is the opinion of the writer that it would be very much worth while to give more attention to parasite infections and to recognize the fact that these infections may often be the cause of an illness attributed to other etiological agents.

## Literature Cited

Headlee, W. H., 1937. The status of human parasite infections in Indiana. Journ. Ind. St. Med. Assoc. **30**:524-526.

Headlee, W. H., 1939. Additional data concerning human intestinal parasite infections in Indiana. Proc. Indiana Acad. Sci. 48:233-237.

Kmecza, J. M., 1939. The incidence of human intestinal parasite infections among patients in a state institution of Indiana. Amer. Journ. Trop. Med. **19**:515-530.

Wenrich, D. H., R. M. Stabler, and J. H. Arnett, 1935. *Endamoeba histolytica* and other intestinal protozoa in 1,060 college freshmen. Amer. Journ. Trop. Med. **15**:331-345.

# Modified Respiratory Movements During Egg Laying in the Hen

N. C. Wheeler, W. C. Randall, and W. A. Hiestand, Purdue University

During some experimental work on the chicken, *Gallus domesticus*, a definite pattern of irregular breathing movements was noticed. A hen, placed in a cabinet[1] preparatory to raising the external temperature, exhibited irregular respiratory rhythm. The hen was subjected to an external temperature of 32°C. The cloacal temperature had increased 0.25°C. above the normal temperature, *i.e.*, the temperature of the cloaca before the application of the external heat.

The normal record of the respiratory movements of the hen is quite similar to that of other vertebrates, the inspiration requiring the greater portion of the time for the respiratory cycle. In Fig. 1, A, the

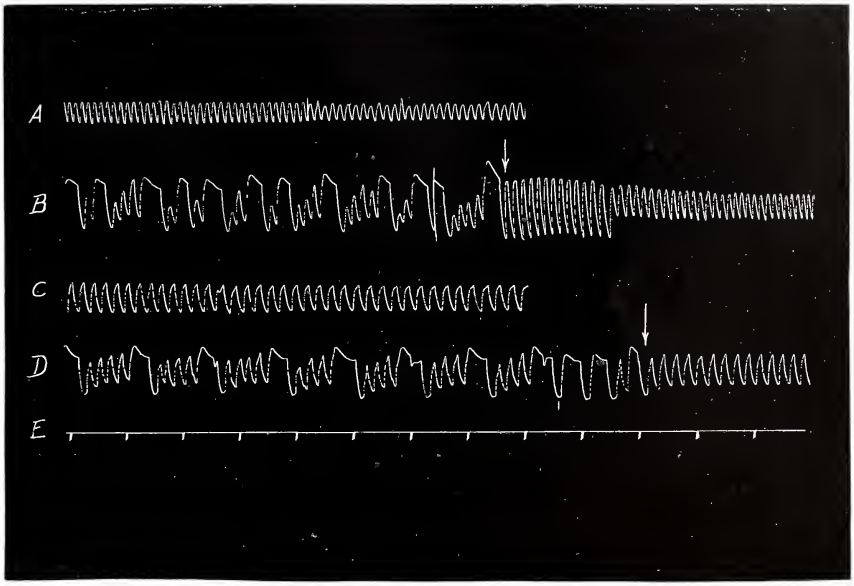


Fig. 1. Respiratory movements during egg laying in the hen. The down stroke of the tambour indicates inspiration.

A. Normal respirations of first hen (40 to 50 per min.).

B. Irregular respiratory movements during egg laying. The arrow indicates time of deposition of egg.

C. Normal respirations of second hen (28 per min.).

D. Irregular respiratory movements during egg laying. The arrow indicates time of deposition of egg.

E. Time intervals, 10 sec.

[1]Hiestand, W. A., and W. C. Randall, 1939. An apparatus for raising the body temperature of small animals. Amer. Mid. Natur. 22:214.

respiratory rate was 40 to 50 per minute and is quite normal for a hen under the increased environmental temperature.

The irregular respiratory rhythm, as shown in Fig. 1, B, was interesting in that following a series of uniform movements apnea occurred at the end of certain expirations. A protrusion of the abdomen indicated the appearance of an egg. As soon as the egg was deposited, as indicated by the arrow, the breathing became regular but was dyspneic during the next 20 seconds after which the amplitude became normal.

Several days later, at the beginning of another experiment, the same type of respiratory movements was observed. This recording (Fig. 1, D) was made at room temperature and is so similar to that made at the higher temperature that the two recordings are presented as representing the character of the breathing movements of a hen while laying an egg. The normal respiratory rate of this hen was 28 per minute.

Both records show essentially the same peculiarities in respiratory rhythm, namely, alternate periods of eupnea and apnea, the latter phase occurring at the end of an expiration and persisting for approximately 3 to 4 seconds. In record 1, B, the dyspneic respiration following expulsion of the egg might be made accountable by an accumulation of an excess of $CO_2$ during the previous period or by the increase in body temperature of the bird in the fever cabinet. The former explanation is the more probable since high body temperature ordinarily causes an increased rate rather than an increased amplitude of respiratory movements in chickens.

An analysis of the modified respiration of the hen during egg laying indicates that periodic held expirations either facilitate mechanically the passage of the egg through the distal portion of the genital tract or occurs as a result of mechanical conditions induced by the passage of the egg.

# Some Gross Anatomical Relations of the Male Urogenital System and Other Internal Organs in *Eumeces fasciatus*.

ALBERT E. REYNOLDS, DePauw University[1]

## Introduction

While the attack on the problems of zoology proceeds with increasing intensity over an ever-widening front, it remains true that, among vertebrates, the reptiles are a relatively neglected group. Phyllogenetic position, physiological considerations centering around poikilothermism, or difficulty of capture or keeping may militate toward this neglect. Another factor may well be that the exact anatomy of most American reptiles has not been worked out. For the experimentalist, therefore, they do not constitute a part of an explored field from which he may select an experimental medium. It is in the hope that a small contribution may be made toward the placing on record of anatomical data on native reptiles that the observations reported here on the red-headed skink, *Eumeces fasciatus*, are presented.

The scincoid *Eumeces fasciatus* may be regarded as a fairly representative American lizard as it has a widespread distribution in the United States (Stejneger and Barbour, 1939; Taylor, 1935). My interest in the animal centered around certain physiological processes and their seasonal variations, approached in part from the standpoint of histological study. For proper prosecution of such studies, a background of knowledge of the gross anatomy had to be developed, and it is to the reporting of some of the gross anatomical relations of these animals that this paper is devoted.

## Material

The skinks that have been examined have been adults or animals only slightly immature. While a few of the animals observed have been from the several counties around the Greencastle (Indiana) area, specimens have also been obtained from Arkansas, Missouri, Tennessee, and Florida. The total number of animals that have passed under scrutiny number several score. Such general statements as occur in this paper are based on the total experience gained in working with these animals; the more specific statements are based on five specimens, animal numbers 4, 53, 54, 55, and 210.

## Methods

In dissection the usual approach by means of a ventral incision through the body wall was employed. Due to extensive subcutaneous connective tissue, the skin is firmly adherent to the subjacent muscular coat.

[1]Approximately half the work upon which this paper is based was done at the Hull Zoological Laboratory, The University of Chicago.

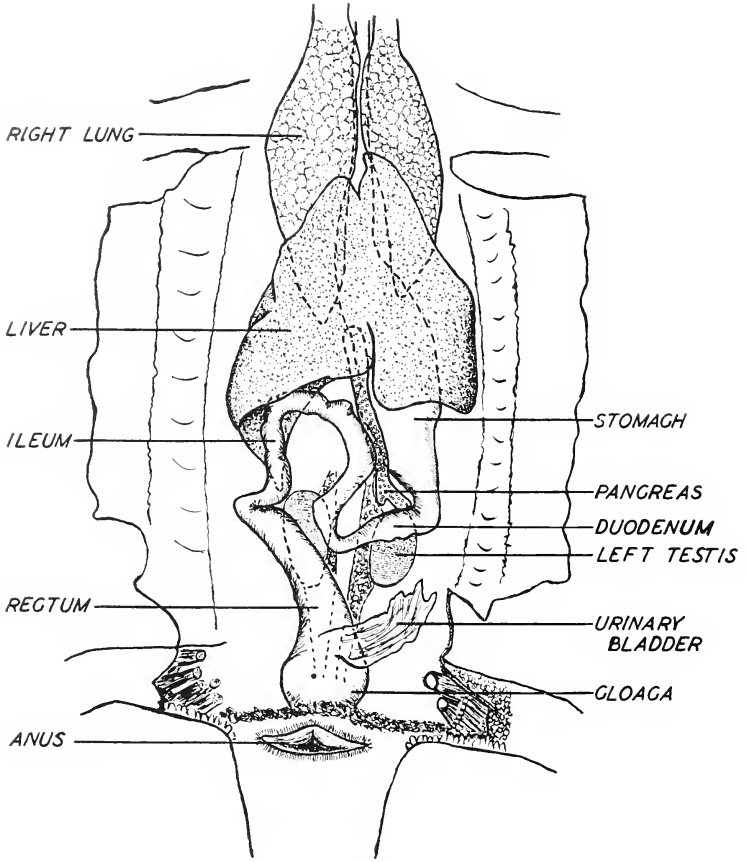


Fig. 1. *Eumeces fasciatus* No. 4. Ventral dissection of young male drawn to scale, showing chief abdominal viscera. For relations, limb outlines, cut muscles, and flaps of body wall tissue shown. (x3)

In *Eumeces fasciatus* the skin is complicated not only by epidermal scales but also by the underlying bony osteoderms of dermal origin. After parting the skin, another incision is passed through the muscular coat (mostly the M. rectus abdominis). Lateral cuts at the limb levels then permitted pinning back of the flaps of body wall tissue. Further dissection, such as removal of muscle, bone, *etc.*, at the girdle levels was carried out as needed.

Figures were drawn to scale, and in each case different degrees of dissection reveal different aspects of the internal anatomy. Figure 1 shows organs visible after opening up the coelom with a minimum of organ displacement. The view seen in Figure 2 required more dissection; that in Figure 3, still more.

Both freshly killed and preserved animals have been examined. All reference to color and appearance is based on the fresh condition. As aids to study, the binocular dissecting microscope and micrometer cali-

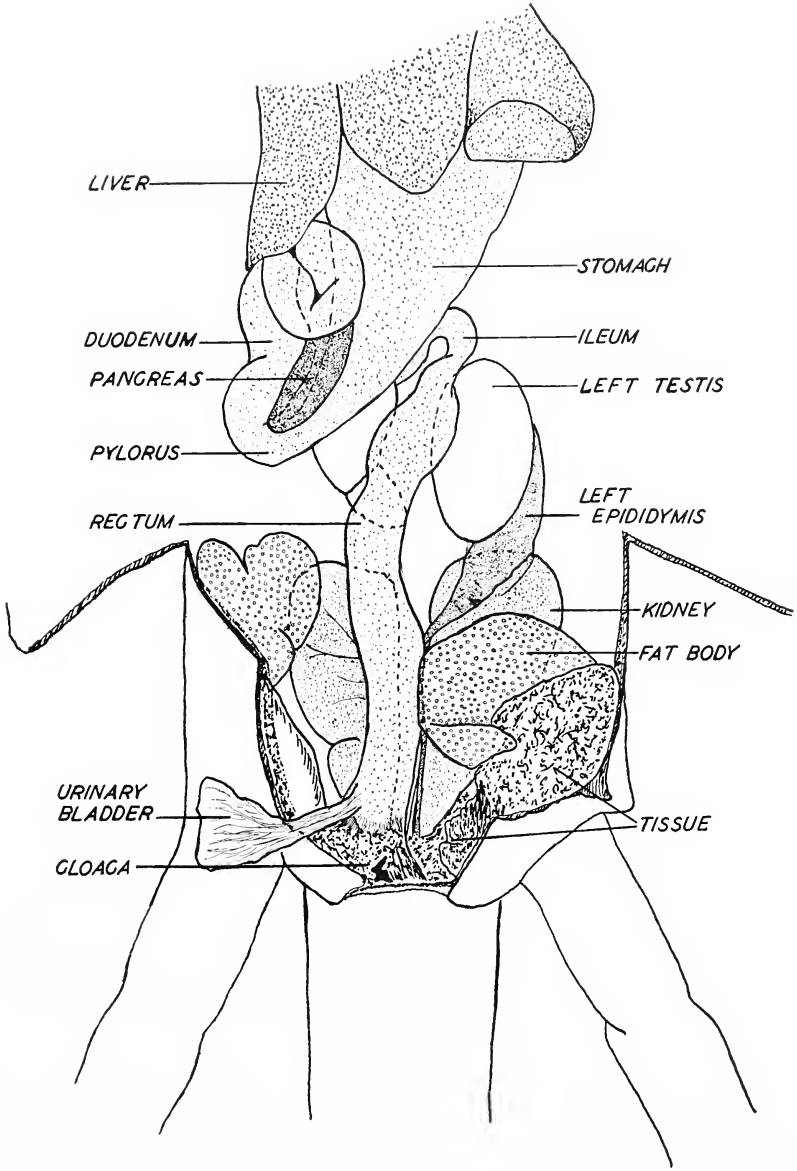


Fig. 2. *Eumeces fasciatus* No. 210. Ventral dissection of mature male, showing part of abdominal viscera and most of urogenital system. Area labelled "tissue" consists of residual cut ends of muscle, connective tissue, *etc.* (x3)

pers were extensively used. Where measurements are expressed in metric units, they do not represent numerical averages or statistical means but are the single measurements of representative specimens.

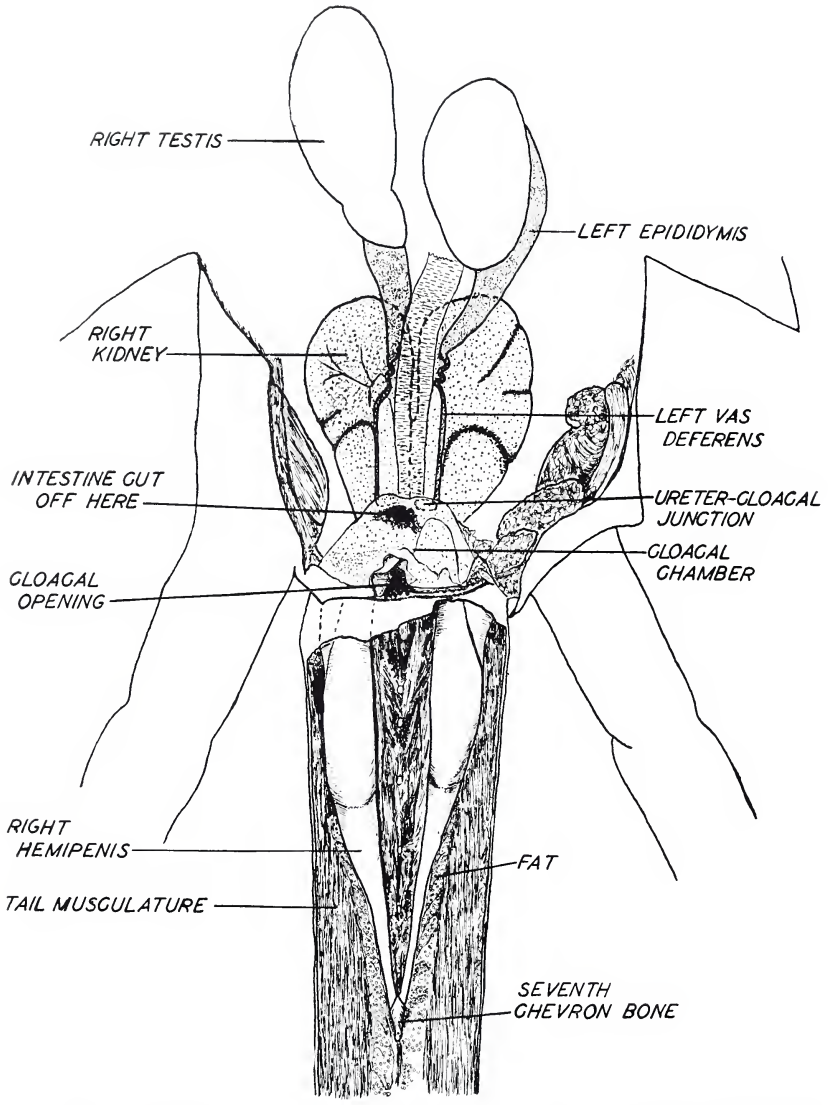


Fig. 3. Specimen No. 210 with viscera removed to reveal further the urogenital organs, and ventral side of tail removed to show hemipenial relations. (x3)

This report is concerned for the most part with the abdominal viscera and the urogenital system in the male. Emphasis was laid on organ relations.

## Literature

Accounts of lizard anatomy are not numerous in English, as Davis (1934) implies. Volume II of Parker and Haswell's (1930) text contains

a discussion based on the European genus Lacerta, and chiefly on *L. viridis*. On American forms Adams (1938) gives figures and a brief description of the iguanid Sceloporus, and Davis (1934) has written a laboratory guide on another iguanid, Crotaphytus. Probably the most comprehensive reference work on lizard anatomy is that of C. K. Hoffman, in the old classic, Bronn's *Thierreich*. The excellent account of

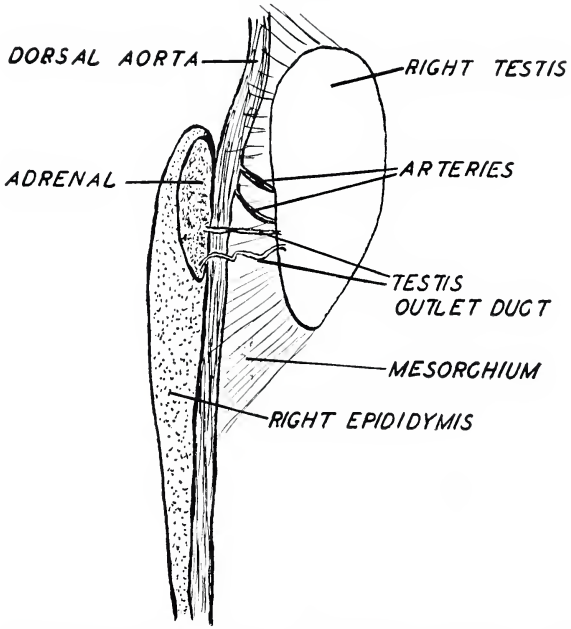


Fig. 4. Right testis of *E. fasciatus* No. 53 displaced to the left, to illustrate testicular blood supply and relations of adrenal gland, epididymis, dorsal aorta, and testis. (x5)

Kraus (1921) is based on *Lacerta agilis* and is written from the standpoint of histology but contains much gross anatomical material. A most exhaustive treatment, when completed, will be that of Bolk et al (1931), and Kükenthal (1931) bases discussion on the interesting primitive lizard, Sphenodon.

## Observations

**General arrangement of parts.**—When the coelom or pleuro-peritoneal cavity is opened as described above, a typically vertebrate arrangement of parts is seen. The sections below describe these parts in more accurate terms.

**1. Heart, lungs, trachea.**—In the anterior end of such a dissection the removal of muscle and bone of the pectoral region reveals that the heart lies directly dorsal to the pectoral girdle. The lungs join the bronchial tubes just dorsal to the heart. The trachea is quite long, its walls containing the characteristic cartilaginous rings. It extends anteriorly ventral to the oesophagus.

The lungs arise at the junction with bronchical tubes, at the heart level, and extend posteriorly into the coelomic cavity (Fig. 1). In animal No. 4 the total length of the lungs is 11.0 mm., their posterior terminations lying 4.0 mm. posterior to the origin of the cardiac end of the stomach.

2. **The digestive tube.**—The oesophagus lies in the median line in a somewhat dorsal position, running anteriorly dorsal to the trachea and being flanked by the lungs posteriorly. The oesophagus enlarges to form cardiac stomach at a point 4.0 mm. anterior to the posterior tip of the lungs in animal No. 4 (Fig. 1).

From the above-mentioned origin of cardiac stomach to the pyloric sphincter, the stomach of No. 4 is 15.0 mm. in length. Specific stomach shape is subject to considerable variation; in general, however, the greatest diameter is near the cardiac end, with a gradual decrease of diameter to the pylorus. The stomach of No. 210 (Fig. 2) conforms to this; that of No. 4 (Fig. 1) is somewhat modified. In No. 4 the stomach lies somewhat to the left of the median line, and almost antero-posteriorly. In No. 210 (Fig. 2), it lies more obliquely. A slight obliqueness of stomach position, from anterior left to posterior right, is the general rule. Exaggerated obliqueness is generally more illusory than real because of differential curvature. The lateral surface of greater curvature may be fairly oblique, especially posteriorly; the medial surface of lesser curvature is much less oblique.

The pylorus is usually evident as a constriction terminating the stomach. The posterior edge of the intestinal tube here is 4.3 mm. anterior to the anterior edge of the kidneys in No. 210 and 16.8 mm. anterior to the ventro-anterior lip of the anus.

From the pylorus the initial part of the small intestine, the duodenum, extends forward, forming with the stomach the J-shaped loop characteristic of vertebrates. The duodenum extends as far forward as the posterior limit of the liver. The anterior edge of the tube at this point in No. 210 is 23.5 mm. anterior to the ventro-anterior anal lip. Hence, it exhibits a difference in level, as compared with pylorus of 6.7 mm., which gives an approximate length for the duodenum. In No. 210 the outer edge of the duodenum is 7.3 mm. to the right of the body midline. (Fig. 2).

From the most anterior level near the liver, the ileum then extends backwards to the rectum. The ileum usually exhibits 2 or 3 loops or curves, the exact arrangement of which is variable, those shown in Figures 1 and 2 being characteristic. In No. 4 the combined length of small intestine, duodenum, and ileum is 24.0 mm. Diameters were not measured but are drawn to scale in the figures.

From the point where the ileum enlarges to form it to the point where it gives rise to the globular cloaca (Figs. 1, 2) the rectum is 9.0 mm. long in No. 4. It is 3.5 mm. in diameter near its posterior end in No. 54. In Lacerta, Parker (1884) and Parker and Haswell (1930) describe a caecum at the junction of ileum and rectum. Adams (1938) figures but does not describe such a caecum for Sceloporus. Davis (1934) mentions one for Crotaphytus as a thin walled enlargement. An asymmetry of rectal expansion is implied in these descriptions. I can find no

similar structure in Eumeces, and any caecal capacity here must be largely capacity for a symmetrical enlargement of the anterior end of the rectum (Fig. 2).

The cloaca is the most posterior region of the digestive tube, of functional significance as excurrent pathways for products not only of the digestive but also of reproductive and urinary systems as well. It is usually of greater diameter than the large intestine, often globular in shape. The study of its posterior chambers is properly a histological one and will be reported later. It opens to the exterior at the anus, a transverse slit (Fig. 1) having in No. 4 a maximum width of 5.5 mm. It coincides in level with the posterior borders of the limbs.

**3. Digestive glands.**—The pancreas is somewhat elongate, lying between the stomach and duodenum and extending forward toward the liver. The latter organ is conspicuous, occupying much coelomic space and ventrally located, thus overlying some organs when viewed ventrally (Fig. 1). In No. 4, from the most anterior tip on the left side of the liver to the posterior border of the same side, the measurement is 11.0 mm. and, from the same tip to the level of the most posterior tip on the right side (concealed by intestine, Fig. 1), 16.5 mm. In No. 210, the right lobe of the liver lies at the same level as the anterior extension of the duodenum, the central lobe terminates 4.3 mm. anterior to this, and the left lobe in turn is 2.8 mm. (with tip turned down, Fig. 2) longer than the central one. The width of the liver is approximately that of the coelomic cavity, tapering anteriorly.

**4. Testis.**—The compact cylindrical testis appears more or less oval when viewed ventrally. It is light yellow in color and lies suspended in the bilateral mesenteric fold, or mesorchium, close to the dorsal body wall.

The lizard testis seems to exhibit typically an asymmetry of anteroposterior level, the right one lying anterior to the left. Such is the case in Sceloporus (Adams, 1938), *L. viridis* (Parker, 1884), and *L. agilis* (Kraus, 1921). The testis of *Eumeces fasciatus* conforms to this scheme (Figs. 1 and 2). In No. 54, the posterior borders of the testis are 1.5 mm. apart in level. In No. 210, the posterior end of the right testis is 0.8 mm. anterior to the same end of the left, but because of greater length its anterior end is 3.0 mm. in front of the anterior end of the left.

Size, shape, and weight of the testis is subject to considerable variation, which is not only among individuals but may also be bilateral in the same individual. Thus, in No. 54, the right testis measures 4.9 mm. x 1.9 mm.; the left 5.0 mm. x 2.0 mm. In No. 210, the right testis is 10.0 mm. x 4.0 mm.; the left 7.4 mm. x 4.0 mm. (Fig. 2). The right testis of No. 53 is 5.0 mm. long.

The testis occupies a quite dorsal position, being overlaid only by the adrenal gland and part of the epididymis (Fig. 3; 4). In No. 53, the testicular blood supply consists of two small branches of the dorsal aorta, the anterior branch entering the testis 2.8 mm. from its anterior end. (Fig. 4) Bilaterally the testis lies with medial borders a short distance from the body midline, the lateral border of the left testis lying 5.0 mm. to the left of the median line in No. 210.

As to antero-posterior level, the testis lies near the pylorus (Fig. 1, No. 4) and near the anterior end of the rectum (Figs. 1, 2). The left testis of No. 54 lies 2.0 mm. in front of the anterior border of the left kidney. In No. 210, the posterior edge of the right testis is 1.9 mm., of the left testis 1.1 mm.; anterior to the foremost edge of the kidney. In the same animal the anterior edge of the left testis is 21.0 mm. anterior to the ventro-anterior lip of the anus, 8.5 mm. in front of the anterior edge of the kidneys, thus extending 4.2 mm. farther forward than the pyloric level (Fig. 2). The posterior edge of the right testis in No. 210 is 14.4 mm. in front of the same anal lip, the posterior edge of the left testis, 13.6 mm. These are then 2.4 mm. and 3.6 mm., respectively, from the pyloric level.

5. **Kidneys.**—The kidneys lie flush against the dorsal muscular body wall, far back posteriorly, in the usual retroperitoneal position. The anterior edge of the kidney, in No. 210, lies 12.5 mm. in front of the antero-ventral anal lip. Each single kidney may be likened to the shape of a right triangle, where the median edge forms a right angle with the anterior edge and the lateral edge forms the hypotenuse. The apex, represented by the posterior tip of the kidney, is far posterior, extending about 2.0 mm. to 3.0 mm. posterior to the level of the anus, lying imbedded in muscle close to the vertebral column. Morphologically the two kidneys are distinct anteriorly, but they become anatomically connected about midway of the length of the two kidneys. Indentations on the lateral edges and grooves on the ventral surfaces mark lobulations of each kidney (Fig. 3), which is a "true kidney" or metanephros.

In animal No. 54, the kidney extends to within 2.0 mm. of the posterior border of the left testis, and the greatest width of the left kidney is 2.5 mm. As indicated above, the kidney in No. 210 comes to within 1.9 mm. and 1.1 mm. of the respective right and left testes and 4.3 mm. of the duodenum. Also in No. 210, the front border of the kidneys extend 12.5 mm. anterior to the ventro-anterior anal lip; hence, they are about 14.5 mm. long to posterior tip. The front edge of the kidney in No. 210 is 8.5 mm. from the posterior edge of the left testis. A band of material is seen passing along covering the medial surfaces of the kidneys in No. 210 (Fig. 3) which consists of blood vessels, peritoneum, and cut mesenteric material.

6. **Other urogenital structures; the adrenal gland.**—The epididymis is fusiform in shape. It widens rapidly from the anterior end to a maximum, then narrows down more gradually to the origin from it of the vas deferens (Fig. 3). The organ is suspended in a fold of the mesorchium, dorsal and lateral to the testis. In animal No. 54, the anterior end of the epididymis is 0.8 mm. posterior to the front end of the right testis; in No. 53, this distance is 1.5 mm.; also on the right side. As seen from the ventral side, the organ emerges from under the lateral border of the left testis 2.3 mm. posterior to the anterior edge of the latter organ in No. 210. The maximum width of the right epididymis in No. 54 is 0.8 mm., and length of both epididymis and vas deferens is 7.8 mm., the two vasa deferentia entering the cloaca at points 1.8 mm. apart. The epididymis extends posteriorly, then obliquely across the anterior ventral

surface of the kidney; then it gives rise to the vas deferens. The latter tube exhibits a few convolutions at its anterior end, then extends posteriorly near the medial edge on the ventral surface of the kidney.

The adrenal gland, golden yellow in color, lies on the medio-ventral surface of the epididymis and is inseparably bound up in the epididymal capsule (Fig. 4).

The ureter is not easily observed, as it is not visible as a distinct tube. It arises at about the last convolution of the vas deferens, and extends as a ridge on the ventral renal surface medial to the vas deferens. It does not emerge as a definite tube to enter the cloaca, as cloacal wall and kidney surface are so closely approximated that an extremely short connection is effected (Fig. 3). Whether the ureter and vas deferens on a side unite before joining the cloaca was not determined.

**7. Hemipenis.**—The copulatory sac or hemipenis may be considered a posterior evagination of the cloacal wall. Surrounded by a sheath, the hemipenis lies among the muscles of the ventro-lateral region of the tail. Anteriorly the organ connects with the posterior cloacal wall near the ventro-lateral corners. At approximately half the total length posterior, the organ changes character, the posterior part undoubtedly being muscular, the anterior part the saccular intromittent organ itself. The entire organ slants medially and dorsally, finally effecting a connection with the seventh chevron bone of the tail. This must be associated with the eleventh caudal vertebra since Taylor (1935) states that chevron bones begin on the fourth caudal vertebra.

**8. Fat storage.**—The corpora adiposa are bilateral masses of fatty tissue lying at the approximate coelomic level of the anterior half of the kidney (Figs. 2, 3). These fat bodies are the usual yellow color and vary greatly in size and weight. Their position is latero-ventral, mostly in front of but partly lying under (dorsal to) the pubic part of the pelvic girdle. It may be of considerable interest to point out that in *E. fasciatus* the fat bodies may be outclassed by the tail as sites of fat deposition. Large masses of fat, segmentally laid down, were dissected from the tail region of No. 210 in preparing it for the drawing seen in Figure 3. Remaining fat is shown in the figure.

## Summary

It has been demonstrated that the abdominal viscera and the urogenital system of *Eumeces fasciatus* is arranged in a typical vertebrate manner. The arrangement of these organs and part-to-part relationships have been described in rather exact terms and supplemented by the presentation of figures.

## Literature Cited

Alverdes, Kurt, 1926. Die Samenableitungswegn der Eidechsen Zeitschr. f. mikroskopisch-anatopisch Forschung 6:420-442.

Adams, Leverett Allan, 1938. An introduction to the vertebrates. John Wiley. New York. Pp. 372-384.

Bolk, Göppert, Kallius, Lubosch, 1931. Handbuch der vergleichenden Anatomie der Wirbelthiere. Uran und Schwarzenburg.

Davis, D. Dwight, 1934. The collared lizard. A laboratory guide. Macmillan. New York.

Hoffman, C. K. Section on reptilia in Bronn's *Klassen und Ordnungen des Thierreichs.*

Kükenthal, Willy, 1931. Handbuch der Zoologie. Bd. 7. Berlin.

Kraus, Rudolph, 1921. Mikroskopische Anatomie der Wirbelthiere in einzel Darstellungen. II. Vogel und Reptilien. Pp. 412-433.

Parker, T. Jeffrey, 1884. Zootomy (vertebrates). Macmillan. London. 4.

Parker, T. J., and Wm. A. Haswell. A textbook of zoology. Macmillan. London. 2:306-326.

Stejneger, Leonhard, and Thomas Barbour, 1939. Checklist of North American reptiles and amphibians. Harvard Univ. Press. Cambridge.

Taylor, Edward H., 1935. A taxonomic study of the cosmopolitan scincoid lizards of the genus Eumeces. Univ. Kansas Sci. Bull. **23**:1-643.

# Notes on Indiana Noctuidae

G. A. FICHT, Purdue University Agricultural Experiment Station

The family Noctuidae has not previously been considered in the surveys of the insect fauna of Indiana. It would, therefore, seem advisable to list the species known to occur in the state and to provide such notes as would add to our knowledge of the various species, particularly concerning those of common occurrence or economic importance.

The moth collections have been largely based on light and bait trap examinations. However, many species have been captured by other means of collection, and many have been reared. Since some species are common throughout the season or may be taken in large numbers throughout various seasonal periods, general notes are often more valuable than actual collection dates. Where very common species which are somewhat numerous at some time or other during the year are discussed, the information is given in general terms which will indicate the insect's abundance and time of appearance. Less common species are attributed the date of collection information.[1] Unless otherwise stated, all collections are attributable to the author. The species are numbered according to Barnes' Check List.[2]

## Genus HELIOTHIS Ochs.

*H. phyloxiphaga* G. & R. (1089).

*Var. luteitinctus* Grt. DeKalb Co., Aug. 11; Tippecanoe Co., Aug. 20 (P.L.)[3]

*H. armiger* Hbn. (1090). Corn earworm, tomato fruitworm, cotton bollworm, and tobacco budworm. Common and destructive during all years in southern part of state, in late fall migrating into northern Indiana in outbreak numbers during some seasons. Commonly found breeding throughout the fall in greenhouses. DeKalb Co., Aug. 1-Oct. 19; Starke Co., April 21 (J.J.D.); Steuben Co., Sept. 6 (G.R.); Tippecanoe Co., Aug. 13 (J.J.D.), Oct. 5 (P.S.C.).

## Genus LYGRANTHOECIA G. & R.

*L. marginata* Haw. (1130). DeKalb Co., June 20-Aug. 12; Tippecanoe Co., June 23 (J.J.D.).

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[1]Determinations of all but the most common and easily recognized species were made by W. T. M. Forbes and J. McDunnough.

[2]Barnes, Wm., and J. McDunnough. Check list of the Lepidoptera of boreal America.

[3]Specimens collected by others than the author are followed by their initials as follows: (J.J.D.) J. J. Davis, (G.E.M.) G. E. Marshall, (G.E.G.) G. E. Gould, (P.S.C.) Purdue Student Collection, (P.L.) P. Luginbill, (A.F.S.) A. F. Satterthwait, (C.R.C.) C. R. Cleveland, (G.R.) G. Ryan, (S.L.M.) S. L. Mason, (F.A.F.) F. A. Fenton, (A.W.T.) A. W. Trippel.

Genus POROSAGROTIS Sm.

*P. vetusta* Wlk. (1234). Spotted-legged cutworm. Reported to be typically associated with sandy country.[4] DeKalb Co., Aug. 8; Tippecanoe Co., Nov. 11 (J.J.D.).

Genus EUXOA Hbn.

*E. quadridentata* G. & R. (1247). DeKalb Co., Sept. 1.

*E. punctigera* Wlk. (1286). Scarce. Washington Co., July 1 (J.J.D.).

*E. velleripennis* Grt. (1291). Common on goldenrod blossoms. DeKalb Co., Sept. 12-23.

*E. messoria* Harris. (1304). Dark-sided cutworm. A common and destructive species. DeKalb Co., July 12-Oct. 19; Tippecanoe Co., July 3, 13, 31 (J.J.D.).

*E. fumalis* Grt. (1312).

Var. *vestitura* Sm. This variety only has been taken. DeKalb Co., June 23.

*E. tessellata* Harris. (1329). Striped cutworm. Common. Less numerous than *messoria* except on gravelly or sandy soils. Dark form also common. DeKalb Co., July 3-Aug. 14; Elkhart Co., June 18 (A.W.T.); Steuben Co., July 11, 14, 28 (G.R.); Tippecanoe Co., emerged June 22, 27 (J.J.D.); Wabash Co., June 18 (A.W.T.).

*E. albipennis* Grt. (1341). Tippecanoe Co., Sept. 14 (J.J.D.).

*E. ochrogaster* Gn. (1363). Tippecanoe Co., July 23, Aug. 25 (J.J.D.).

Genus FELTIA Wlk.

*F. gladiaria* Morr. (1395). Clay-backed cutworm. Abundant from early September through October. DeKalb Co., Sept. 9-Oct. 22; Tippecanoe Co., Sept. 25, Oct. 5 (J.J.D.), Oct. 9 (P.S.C.).

*F. venerabilis* Wlk. (1397). Dusky cutworm. DeKalb Co., Sept. 3; Tippecanoe Co., Sept. 9 (P.S.C.), Oct. 5 (J.J.D.).

*F. ducens* Wlk. (1402). Dingy cutworm. Common and destructive. Numerous from August through October. DeKalb Co., Aug. 6-Oct. 19; Gibson Co., emerged Sept. 18 (J.J.D.); Greene Co., emerged Aug. 21, Sept. 9, 17, 19, Oct. 4 (J.J.D.); Monroe Co., emerged Sept. 1 (J.J.D.); Steuben Co., Aug. 4, Sept. 1 (G.R.); Tippecanoe Co., emerged Aug. 3-Sept. 21 (J.J.D.); Vanderburgh Co., emerged Sept. 21 (J.J.D.).

*F. subgothica* Haw. (1403). Dingy cutworm. Less numerous than *ducens;* occurring at approximately the same time. Clinton Co., Sept. 2 (J.J.D.); DeKalb Co., Aug. 15-Sept. 13; Gibson Co., Aug. 30, Sept. 18 (J.J.D.); Greene Co., emerged Aug. 6, Sept. 12, 13, 19 (J.J.D.); Steuben Co., Aug. 9, 17 (G.R.); Tippecanoe Co., Aug. 13, 27 (P.S.C.), Sept. 3 (J.J.D.).

*F. herilis* Grt. (1404). DeKalb Co., Aug. 28-Sept. 15; Steuben Co., Aug. 7 (G.R.).

*F. volubilis* Harv. (1409). DeKalb Co., May 29, 31; Tippecanoe Co., May 11 (P.S.C.).

[4]Forbes, W. T. M., 1926. A check list of the insects of New York. Cornell Univ. Agric. Exp. Sta., Mem. No. 101. 1926.

*F. annexa* Treit. (1413). Granulated cutworm. DeKalb Co., Aug. 23; Orange Co., Aug. 21 (G.E.M.).

*F. malefida* Gn. (1414). Pale-sided cutworm. DeKalb Co., July 23-Sept. 3.

Genus AGROTIS Ochs.

*A. badinodis* Grt. (1415). Spotted-sided cutworm. Common. DeKalb Co., Sept. 2, 10, 23; Steuben Co., Aug. 4 (G.R.); Tippecanoe Co., Aug. 18-Sept. 29 (J.J.D.).

*A. ypsilon* Rott. (1422). Greasy cutworm, black cutworm, and overflow worm. One of the most numerous and destructive cutworms, particularly in muck soils and in poorly drained areas. Numerous from May to October. DeKalb Co., May 3-Oct. 14; Gibson Co., emerged Aug. 4-24 (J. J. D.); Greene Co., emerged July 30 (J.J.D.); Posey Co., emerged Oct. 25 (J.J.D.); Shelby Co., emerged Aug. 25 (J.J.D.); Tippecanoe Co., Sept. 2-Oct. 21 (J.J.D.).

*A. c-nigrum* L. (1424). Spotted cutworm. Numerous from May to October. DeKalb Co., May 18-Oct. 19; Greene Co., emerged May 20 (J.J.D); Huntington Co., emerged May 28 (J.J.D.); Starke Co., emerged Aug. 15-Sept. 11 (J.J.D.); Steuben Co., June 11, 12, 16, 24 (G.R.); Tippecanoe Co., emerged July 12-Sept. 7 (J.J.D.); Warren Co., emerged July 19 (J.J.D.).

*A. bicarnea* Gn. (1425). A common cutworm. DeKalb Co., Aug. 15-Sept. 14; Tippecanoe Co., May 16, July 28 (J.J.D.).

*A. baja* Fabr. (1430). DeKalb Co., July 1.

*A. plecta* L. (1434). A common cutworm. DeKalb Co., May 29-July 29; Steuben Co., June 4, 16 (G.R.); Tippecanoe Co., July 25 (J.J.D.).

*A. phyllophora* Grt. (1444). Unmarked cutworm. DeKalb Co., July 6.

*A. unicolor* Wlk. (1461). W-marked cutworm. Common in sandy and gravelly soils in northern Indiana. DeKalb Co., June 1-July 30; Elkhart Co., June 2-Aug. 4; Fulton Co., June 8 (J.J.D.); Steuben Co., Sept. 6 (G.R.).

*A. lubricans* Gn. (1502). DeKalb Co., June 2-July 25.

Genus EPIPSILIA Hbn.

*E. fungorum* G. & R. (1471). A cutworm. DeKalb Co., Sept. 21.

Genus LYCOPHOTIA Hbn.

*L. occulta* L. (1489). A cutworm. DeKalb Co., Aug. 21.

*L. margaritosa* Haw. (1490). Variegated cutworm. Common from June to October. One of the most numerous and destructive cutworms.

Var. *saucia* Hbn. Occurs at the same time as the typical form.

Var. *semifusca* Butl. is found commonly together with the normal species and the var. *saucia* Hbn. The species breeds throughout the winter in greenhouses where the var. *semifusca* Butl. is frequently the most numerous. DeKalb Co., June 3-Oct. 17; Starke Co., emerged Sept. 12, 18 (J.J.D.); Steuben Co., June 23, Aug. 17, 19 (G.R.); Tippecanoe Co., emerged July 6-Oct. 14 (J.J.D.).

*L. infecta* Ochs. (1495). Green cutworm. DeKalb Co., Aug. 2.

*L. lubricans* Gn. (1502). DeKalb Co., Aug. 10.

Genus RYNCHAGROTIS Sm.

*R. rufipectus* Morr. (1565). Common. DeKalb Co., June 16-Aug. 16.

*R. alternata* Grt. (1588). Mottled-gray cutworm. Common. DeKalb Co., June 14-Sept. 4; Tippecanoe Co., emerged June 11-July 8 (J.J.D.).

*R. anchocelioides* Gn. (1589). Reared from larvae taken in sandy and gravelly soils. Elkhart Co., emerged June 17, 20; Steuben Co., May 19 (G.R.).

*R. cupida* Grt. (1590). Brown cutworm. A common and destructive climbing cutworm in orchards. Confined largely to sandy and gravelly soils. Elkhart Co., emerged June 14-July 18; Tippecanoe Co., July 3 (J.J.D.).

*R. barnesi* French. (....). Barnes' climbing cutworm. The most common and destructive climbing cutworm affecting orchards. Confined largely to light soils. Elkhart Co., emerged June 14-July 26.

Genus SCOTOGRAMMA Sm.

*S. trifolii* Rott. (1615). Clover cutworm. Common throughout Indiana. DeKalb Co., June 2-Sept. 14; Steuben Co., July 5-Aug. 30 (G.R.); Tippecanoe Co., Aug. 3 (J.J.D.).

Genus POLIA Ochs.

*P. imbrifera* Gn. (1661). DeKalb Co., July 14.

*P. meditata* Grt. (1673). Pink-backed cutworm. Common. DeKalb Co., July 5-Sept. 13.

*P. grandis* Bdv. (1685). A cutworm. DeKalb Co., June 17, 21.

*P. subjuncta* G. & R. (1686). Speckled cutworm. A common species occurring throughout the area from May to September. DeKalb Co., May 28-Sept. 13; Steuben Co., June 11-Aug. 17 (G.R.); Tippecanoe Co., Aug. 5 (J.J.D.).

*P. cristifera* Wlk. (1693). Not common. But one specimen has been taken. DeKalb Co., June 2.

*P. latex* Gn. (1695). A cutworm. One specimen has been taken. DeKalb Co., June 7.

*P. adjuncta* Bdv. (1700). Allen Co., May 28.

*P. legitima* Grt. (1715). Striped garden caterpillar. Common and destructive. DeKalb Co., June 10-Sept. 12.

*P. renigera* Steph. (1750). Bristly cutworm. The commonest cutworm of this genus, occurring in two broods from May to October. DeKalb Co., May 27-Oct. 16; Greene Co., emerged June 7, 10 (J.J.D.); Orange Co., emerged Sept. 12 (J.J.D.); Starke Co., emerged Sept. 5, 6 (J.J.D.); Tippecanoe Co., July 12-Oct. 1 (J.J.D.); Wayne Co., emerged Sept. 7, 12 (J.J.D.).

*P. lorea* Gn. (1754). A general and common cutworm but not a serious pest. DeKalb Co., June 4-17.

Genus CHABUATA Wlk.

*C. signata* Wlk. (1798). DeKalb Co., Aug. 8; Tippecanoe Co., emerged Aug. 22 (J.J.D.).

Genus ERIOPYGA Gn.

*E. crenulata* Butl. (1838). A cutworm. Common. DeKalb Co., June 6-Sept. 2.

*E. synica* Gn. (1839). A cutworm. July 7, 8.

*E. vecors* Gn. (1842). A cutworm. DeKalb Co., May 28.

Genus NEPHELODES Gn.

*N. emmedonia* Cram. (1866). Bronze cutworm. A common cutworm. DeKalb Co., Sept. 4-Oct. 19; Tippecanoe Co., Sept. 4, 9, 12, 14 (J.J.D.).

Genus MORRISONIA Grt.

*M. confusa* Hbn. (1878). Posey Co., May 14 (J.J.D.).

Genus ORTHOSIA Ochs.

*O. germani* Grt. (1915). Greene Co., April 11 (J.J.D.).

*O. hibisci* Gn. (1919).

Var. *alia* Auct. A "green fruitworm" on apple. The following records are of this variety: Tippecanoe Co., Nov. 25, May 9 (P.L.).

Genus CERAMICA Gn.

*C. picta* Harr. (1930). Zebra caterpillar. Common. DeKalb Co., May 14-July 10; Greene Co., May 16 (A.F.S.); Tippecanoe Co., May 20 (P.S.C.).

Genus CIRPHIS Wlk.

*C. pseudargyria* Gn. (1933). DeKalb Co., June 16; Steuben Co., June 2, July 12 (G.R.); Tippecanoe Co., May 3, emerged Aug. 9, Sept. 13 (J.J.D.).

*C. commoides* Gn. (1935). Apparently rare. DeKalb Co., June 28.

*C. phragmatidicola* Gn. (1936). Yellow armyworm. An armyworm common from May to October. DeKalb Co., May 23-Oct. 6; Steuben Co., June 11, 15, 19 (G.R.); Tippecanoe Co., Aug. 2, 18 (J.J.D.).

*C. unipuncta* Haw. (1950). Common armyworm. Abundant throughout the season from early May to October and frequently widely destructive. Clinton Co., July 16, 17 (C.R.C.); DeKalb Co., May 12-Oct. 19; Fulton Co., emerged July 31 (J.J.D.); Starke Co., July 10 (C.R.C.); Steuben Co., June 6, 26, July 4 (G.R.); Tippecanoe Co., May 7-Oct. 28 (J.J.D.).

*C. inermis* Fbs. (....). DeKalb Co., June 11.

*C. ursula* Fbs. (....). Common. DeKalb Co., June 28-Aug. 8.

Genus NELEUCANIA Sm.

*N. albilinea* Hbn. (1959).

Var. *diffusa* Wlk. Wheat-head armyworm. Both forms present and common. Clark Co., April 15-Aug. 23 (P.S.C.); DeKalb Co., June 17-Aug. 11; Fulton Co., emerged Aug. 23 (J.J.D.); Kosciusko Co., emerged Aug. 27 (J.J.D.); Tippecanoe Co., May 13, 28 (P.S.C.).

Genus CUCULLIA Schrank

*C. asteroides* Gn. (2003). Clark Co., April 12-Aug. 23 (P.S.C.); DeKalb Co., June 22-Aug. 4; Sullivan Co., Aug. 12 (J.J.D.); Tippecanoe Co., May 11, 13, 15, 16, 20, 21, 28 (P.S.C.).

Genus EUTOLYPE Grt.

*E. depilis* Grt. (2109). DeKalb Co., April 4.

Genus GRAPTOLITHA Hbn.

*G. bethunei* G. & R. (2131). DeKalb Co., April 27; Tippecanoe Co., Sept. 25 (J.J.D.).

*G. innominata* Sm. (2133). Tippecanoe Co., March 25 (P.L.).

*G. ferrealis* Grt. (2137). Tippecanoe Co., Sept. 26 (J.J.D.).

*G. signosa* Wlk. (2139). Tippecanoe Co., emerged Sept. 2 (J.J.D.).

*G. unimoda* Lint. (2150). DeKalb Co., Oct. 21; Tippecanoe Co., March 25 (P.L.).

Genus PARASTICHTIS Hbn.

*P. bicolorago* Gn. (2220).

Var. *ferrugineoides* Gn. Shield-marked cutworm. These moths appear in numbers in late fall. DeKalb Co., Sept. 14-Oct. 19; Greene Co., July 31 (A.F.S.).

Genus ATETHMIA Hbn.

*A. pampina* Gn. (2230). DeKalb Co., Aug. 8.

Genus AMPHIPYRA Ochs.

*A. pyramidoides* Gn. (2239). Common in bait traps. Clark Co., June 20-July 28 (P.S.C.); DeKalb Co., July 27-Sept. 26.

*A. tragopoginis* L. (2240). DeKalb Co., Aug. 8, Sept. 9.

Genus DIPTERYGIA Steph.

*D. scabriuscula* L. (2243). Numerous during the summer months. DeKalb Co., June 2-Sept. 17; Tippecanoe Co., July 31 (F.A.F.), Aug. 13, 27, Sept. 15 (J.J.D.).

Genus SEPTIS Hbn.

*S. verbascoides* Gn. (2246). DeKalb Co., June 2, 3; Elkhart Co., June 21.

*S. cariosa* Gn. (2248). DeKalb Co., July 31.

*S. lignicolor* Gn. (2253). Common and numerous. DeKalb Co., June 6-July 14.

*S. plutonia* Grt. (2264). DeKalb Co., June 16-July 14.

*S. arctica* Bdv. (2268). Yellow-headed cutworm. A common and destructive species. DeKalb Co., June 9-Aug. 9; Steuben Co., July 12, 23 (G.R.).

Genus TRACHEA Ochs.

*T. delicta* Grt. (2271). Numerous. DeKalb Co., June 1-Aug. 17; Tippecanoe Co., emerged May 29 (J.J.D.).

Genus PERIGEA Gn.

*P. xanthoides* Gn. (2323). DeKalb Co., June 20.

*P. vecors* Gn. (2327). DeKalb Co., July 11, Sept. 13.

Genus OLIGIA Hbn.

*O. fractilinea* Grt. (2335). DeKalb Co., July 16.

Var. *modiola* Grt. is more common. DeKalb Co., July 16, 17, Aug. 18, 20.

*O. diversicolor* Morr. (2339). Delaware Co., Aug. 21 (A.F.S.).

Genus AGROPERINA Hamp.

*A. dubitans* Wlk. (2344). A common cutworm. DeKalb Co., June 2-Sept. 14.

*A. helva* Grt. (2357). DeKalb Co., Aug. 1-15.

Genus MACRONOCTUA Grt.

*M. onusta* Grt. (2365). Iris borer. DeKalb Co., June 30.

Genus SIDEMIA Staud.

*S. devastator* Brace. (2367). Glassy cutworm. Common and destructive. DeKalb Co., June 17-Sept. 23; Tippecanoe Co., Aug. 5 (J.J.D.).

Genus LUPERINA Bdv.

*L. passer* Gn. (2380). DeKalb Co., Aug. 13.

Genus PHLOGOPHORA Tr.

*P. iris* Gn. (2384). DeKalb Co., June 13.

Genus LEUCONYCTA Hamp.

*L. diphteroides* Gn. (2418). DeKalb Co., May 18.

Var. *obliterata* Grt. is more common. DeKalb Co., May 18-Aug. 26.

Genus ACRONYCTA Ochs.

*A. connecta* Grt. (2433). DeKalb Co., July 28.

*A. pruni* Harr. (2438). DeKalb Co., June 20-July 1.

Var. *prunata* S. & B. appears to be scarce. DeKalb Co., May 28.

*A. inclara* Sm. (2444). DeKalb Co., Aug. 8.

*A. afflicta* Grt. (2450). DeKalb Co., Aug. 10, 22, July 7; St. Joseph Co., July 10 (A.W.T.).

*A. hasta* Gn. (2461). The dark form only has been taken. DeKalb Co., July 28.

*A. elizabeta* Sm. (2466). DeKalb Co., July 28, Aug. 8.

*A. morula* G. & R. (2473). Only the dark form has been taken. DeKalb Co., July 11, 28.

*A. interrupta* Gn. (2474). DeKalb Co., June 28, July 27, 28.

*A. populi* Riley. (2483). DeKalb Co., Aug. 12.

*A. americana* Harris. (2491). DeKalb Co., June 23; Steuben Co., July 12 (G.R.).

*A. oblinita* A. & S. (2508). DeKalb Co., June 22, July 2, Aug. 8, 16.

*A. insolita* Grt. (2510). DeKalb Co., Aug. 12.

Genus SIMYRA Ochs.

*S. henrici* Grt. (2514). DeKalb Co., June 22, 24, July 22.

Genus DELTA Saalm.

*D. ramosula* Gn. (2515). DeKalb Co., May 20, Oct. 12; Posey Co., Nov. 8 (S.L.M.).

Genus HYPPA Dup.

*H. xylinoides* Gn. (2531). Very numerous. DeKalb Co., May 18-Sept. 4.

Genus PRODENIA Gn.

*P. ornithogalli* Gn. (2569). Yellow-striped armyworm, cotton cutworm. Common throughout the state, frequently occurring in outbreak numbers. DeKalb Co., June 18-Oct. 19; Tippecanoe Co., Aug. 31 (A.F.S.), April 19-Nov. 2 (J.J.D.).

Genus LAPHYGMA Gn.

*L. frugiperda* A. & S. (2574). Fall armyworm. Probably a migrant to northern Indiana, occurring in limited numbers in September and October. DeKalb Co., Sept. 30, Oct. 6; Tippecanoe Co., Sept. 12 (J.J.D.); Dearborn Co., Nov. 10, 13 (C.R.C.).

Genus CARADRINA Ochs.

*C. tarda* Gn. (2581). DeKalb Co., Aug. 12.

Genus PROXEMUS H. S.

*P. miranda* Grt. (2990). DeKalb Co., June 11; Tippecanoe Co., emerged April 19 (J.J.D.).

Genus PLATYSENTA Grt.

*P. videns* Gn. (2598). DeKalb Co., May 3, June 11.

Genus BALSA Wlk.

*B. malana* Fitch. (2600). DeKalb Co., May 27, June 1, 17.

Genus HELIOTROPHA Led.

*H. reniformis* Grt. (2636). DeKalb Co., Oct. 1.
Var. *arta* Grt. DeKalb Co., July 25, 30, Oct. 3.

Genus APAMEA Ochs.

*A. velata* Wlk. (2637). DeKalb Co., June 18, 23, July 13.

Genus ACHATODES Gn.

*A. zeae* Harris. (2642). DeKalb Co., Aug. 5.

Genus PAPAIPEMA Sm.

*P. inquaesita* G. & R. (2661). DeKalb Co., Sept. 28.
*P. marginidens* Gn. (2663). Allen Co., Aug. 24, 28; DeKalb Co., Aug. 17.
*P. furcata* Sm. (2667). DeKalb Co., Aug. 1, 4.
*P. cataphracta* Grt. (2686). DeKalb Co., Sept. 23, 28.

*P. cerussata* Grt. (2696). DeKalb Co., Sept. 6.

*P. nebris* Gn. (2698). Common stalk borer. Allen Co., Aug. 24, 29.

Var. *nitela* Gn. DeKalb Co., Sept. 9, 23, 25; Tippecanoe Co., Aug. 12 (J.J.D.).

Genus IPIMORPHA Hbn.

*I. pleonectusa* Grt. (2724). DeKalb Co., July 27.

Genus ARZAMA Wlk.

*A. obliqua* Wlk. (2784). Fulton Co., May 23 (J.J.D.); Tippecanoe Co., emerged May 8, 11 (J.J.D.).

Genus ARCHANARA Hbn.

*A. sublava* Grt. (2792). DeKalb Co., Aug. 11.

Genus EUTHASONOTIA Hbn.

*E. grata* Fabr. (2827). Porter Co., June 27 (A.W.T.); Allen Co., June 23, 28; DeKalb Co., May 5.

Genus CHAMYRIS Gn.

*C. cerintha* Treit. (2891). DeKalb Co., June 11, July 15; Tippecanoe Co., June 14 (G.E.G.).

Genus LETHACODIA Hbn.

*L. carneola* Gn. (2900). DeKalb Co., May 25, 26; Tippecanoe Co., June 13 (G.E.G.).

Genus CATOCALA Schrank.

*C. innumbens* Gn. (3020). DeKalb Co., June 28, July 17, Aug. 6, 13.
*C. epione* Drury. (3023). DeKalb Co., July 23, Aug. 16.
*C. obscura* Stkr. (3025). DeKalb Co., July 29.
*C. palaeograma* Gn. (3045). DeKalb Co., Aug. 6, 10.
*C. ilia* Cram. (3051). DeKalb Co., July 8, 29, Aug. 8.
*C. marmorata* Edw. (3045). DeKalb Co., Aug. 11, 13.
*C. unijuga* Wlk. (3068). DeKalb Co., July 3.
*C. cara* Gn. (3081). DeKalb Co., July 26, 28, Aug. 13, 22.
*C. concumbens* Wlk. (3082). DeKalb Co., Aug. 5, 6, 11.
*C. amatrix* Hbn. (3083). DeKalb Co., Aug. 10, 13, 26.
*C. illecta* Wlk. (3088). DeKalb Co., July 10, 28, Aug. 6, 8.
*C. ultronia* Hbn. (3103). DeKalb Co., July 23, Aug. 10.
*C. grynea* Cram. (3106). DeKalb Co., July 22, Aug. 10.

Genus PARALLELIA Hbn.

*P. bistriaris* Hbn. (3127). DeKalb Co., June 11, July 16.

Genus CAENURGIA Wlk.

*C. erechtea* Cram. (3135). An alfalfa looper. Common. DeKalb Co., May 22-Aug. 29; Tippecanoe Co., April 26 (G.E.G.).

*C. crassuiscula* Harr. (3136). DeKalb Co., May 12.

Genus ARGYROSTROTIS Hbn.

*A. anilis* Dru. (3164). DeKalb Co., June 17, 19, July 6, Aug. 10; Tippecanoe Co., Sept. 5 (J.J.D.).

Genus ZALE Hbn.

*Z. lunata* Dru. (3175). Common. DeKalb Co., June 10-Aug. 21; Steuben Co., June 14 (J.J.D.).

Genus AUTOGRAPHA Hbn.

*A. falcifera* Kirby. (3230). Celery looper. Tippecanoe Co., June 1 (G.E.G.); DeKalb Co., May 2, 4, June 30, July 26.

*A. brassicae* Riley. (3249). Cabbage looper. Very common and sometimes destructive. DeKalb Co., July 9, Aug. 5; Tippecanoe Co., Aug. 19 (G.E.G.); Steuben Co., Aug. 6 (G.R.).

*A. basigera* Wlk. (3251). DeKalb Co., June 25, 26.

*A. biloba* Steph. (3259). DeKalb Co., May 3, 6, June 28, July 26.

*A. oo* Cram. (3260). DeKalb Co., May 8.

Var. *rogationis* Gn. Starke Co., Sept. 14 (J.J.D.); Starke Co., Aug. 21 (J.J.D.).

*A. pseudogemma* Grt. (3266). DeKalb Co., June 18.

Genus PLUSIA Ochs.

*P. aerea* Hbn. (3276). DeKalb Co., June 2, 19, 28.

*P. balluca* Geyer. (3277). DeKalb Co., June 26.

Genus ABROSTOLA Ochs.

*A. urentis* Gn. (3286). DeKalb Co., June 28.

Genus MELIPOTIS Hbn.

*M. jucunda* Hbn. (3312). DeKalb Co., July 22, Aug. 26.

Genus TOXOCAMPA Gn.

*T. victoria* Grt. (3338). DeKalb Co., June 2, July 22, 23.

Genus STRENOLOMA Grt.

*S. lunilinea* Grt. (3365). DeKalb Co., June 17, 28.

Genus SCOLIOPTERIX Germ.

*S. libatrix* L. (3399). DeKalb Co., July 14, June 23; Steuben Co., June 3, July 3, 11 (G.R.).

Genus PLUSIODONTA Gn.

*P. compressipalpis* Gn. (3400). DeKalb Co., June 15, July 16; Lawrence Co., May 3 (G.E.M.); Porter Co., July 28 (A.W.T.).

Genus ALABAMA Grt.

*A. argillacea* Hbn. (3406). Cotton worm. Occurs during late summer and fall, a probable migrant from the South. DeKalb Co., Sept. 28, 30; Greene Co., Sept. 26 (J.J.D.); Greene Co., emerged June 23 (J.J.D.).

Genus EPIZEUXIS Hbn.

*E. lubricalis* Geyer. (3496). Elkhart Co., June 11.

Genus HORMISA Wlk.

*H. bivittata* Grt. (3514). DeKalb Co., July 13.
*H. orciferalis* Wlk. (3515). Greene Co., emerged June 23 (J.J.D.).

Genus BOMOLOCHA Hbn.

*B. bijugalis* Wlk. (3562). DeKalb Co., May 20, 28, 30, June 20.

Genus PLATHYPENA Grt.

*P. scabra* Fabr. (3578). DeKalb Co., July 6.

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